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A System Dynamic Model of Leader Emergence

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THESIS

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Abstract

The purpose of this thesis is to develop a system dynamics model of leader emergence. Longitudinal social network and personality data were collected in a class of enlisted military professionals attending a six week leadership development course. Findings support known relationships in existing leadership research. This thesis demonstrates the applicability of system dynamics toward the complex social phenomena of leader emergence.

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First, to Myself.

More importantly, to all those that have made me who I am…

My loving Wife, Father, Mother, and Brother,

and all my loving and supportive friends and family.

Acknowledgments

I would like to extend personal thank you to LtCol Halverson who has displayed an inordinate amount of consideration and humanity during my time here at the glorious halls of AFIT. Thank you for allowing me to the opportunity to fail forward, and treating me not as though I can make it, but as though I am expected to excel.

I'd also like to explain how appreciative I am of the tutelage of Dr. Mike Shelley. He patiently guided my many ill self-directed efforts, and through it all I began to see what I was unable to see before. His knowledge of System Dynamics is undeniably impressive. But on top of his firm handle on the subject, he's been a fun person to learn from.

Paul S. Wever

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Table of Contents

List of Figures

Figure Page

Figure Page

Figure Page

List of Tables

Table Page

A SYSTEM DYNAMIC MODEL OF LEADER EMERGENCE

I. Introduction

Leader Emergence Background

Leadership exists across all human cultures, and the study of history has followed the motivations and actions of societies' leaders. Leadership is an important concept because of its potential to affect outcomes of organizations such as families, workgroups, businesses, and governments. Even when no formal leader is designated, central players arise in group decision making across all cultures. Leader emergence occurs through interaction; it is a collective process by which one individual is selected over others to best lead the group (Bass, 1990). Leadership research is encouraging new methods used to conceptualize and analyze this universal cultural phenomenon.

Leadership research is replete with correlation studies that support static relationships between predictors and criterion (Bono & Judge, 2004; Judge, Bono, Ilies, & Gerhardt, 2002; Eagly, Johanneses-Schmidt, & Van Engen, 2003; Taggar, Hackett, & Saha, 1999; Stogdill, 1948). The agglomeration of empirically correlated variables has supported increasingly complicated theories of leadership (Bass, 1990; Northouse, 2007; Bass, Avolio, Jung, & Berson, 2003; Yukl, 1989). As the understanding of leadership advances, interest in applying new methods toward leadership research is also increasing (Hazy, 2007). Linear cause and effect models have resulted in the current conceptualization of leadership and leader emergence. As leadership research continues, it may benefit from the use of non-linear leadership models (Hunt & Ropo, 2003).

Non-linear Conceptualization of Leader Emergence

Whereas deterministic mathematical equations capture unique interactions between individual objects, and statistics captures patterns of interactions between many objects, complexity science studies the dynamic interactions between moderate numbers of objects (Weaver, 1948). Complex Adaptive System (CAS), the conceptual model of an organization (Dooley, 1997), is a fundamental concept surfacing from the fusion of complexity and organizational sciences. Applying complexity science to leadership research expands previous notions of leadership beyond dyadic, non-reciprocal interactions between leaders and followers to multiple interdependent interactions of individuals within CASs (Guastello, 2007; Plowman, Solansky, Beck, Baker, Kulkarni, & Villareal Travis, 2007; Uhl-Bien, Marion, & McKelvey, 2007). Successfully modeling behaviors which affect leader emergence can greatly assist in selecting individuals for leader roles, developing leadership programs, and understanding the role leaders and non-leaders play in the outcomes of groups.

Social network analysis provides precise definitions for patterns of relationships within groups (Wasserman & Faust, 1994). Longitudinally recording CAS actor to actor interactions will identify time-series behaviors which may exist in social network measures. Time dependent behaviors can then be analyzed for characteristics using system dynamics methodology. System dynamics provides a method for understanding the interdependencies that cause linear and/or non-linear behaviors.

System Dynamics as a Methodology in Leader Emergence

System dynamics emerged from the study of electrical control systems, and when generalized found many useful applications in natural systems outside of the electrical world (Forrester, 1992). Whereas correlations describe cause and effect relationships in a linear equation, system dynamics extends causal thinking one step further by suggesting that flows, such as the rate at which water flows, influence stocks, such as the level (stock) of water in a bucket, interdependently. The result is that changes to the stock, an increase in the bucket's water level, also influence the flow, leads to a decrease in the rate at which one fills the bucket. When plotted over time, a system (the arrangement of flows and stocks) behaves in a way that is unique to its structure (Sterman, 2000; Forrester, 1968). Using available longitudinal behavior, system dynamics methods can propose and validate interdependent system structures, providing a means of analyzing non-linear systems. When applied to leadership research, leader emergence can be investigated as a result of interdependent systems of personality influencing the CAS, and CAS behaviors influencing the emergent leader.

II. Literature Review

Leader Emergence

Definitions of leadership generally depend on their context, but Judge & Robbins (2007) suggest a general definition as "the ability to influence a group toward the achievement of a vision or set of goals" (p. 402). While this definition captures the act of leading, the idea of an individual rising to the role of a leader from within an organization is a different matter. Leader emergence, the area of focus in this study, is phrased by Bass (1990) as "the consequence of interactions within the group that arouse expectations that he or she, as opposed to someone else, can serve the group most usefully by helping it to attain its objectives" (p. 16). Leader emergence, according to this definition, is a reciprocal arrangement among group members. Actions of leaders within a group are a result of, and initiate, actions among members which in turn, have impacts on the success of the leader and the organization (Jung & Avolio, 1999). Group members can modify behaviors such as dissent/consent, to exert control over the leader's success (Collinson, 2005). In this way, a leader is influenced by the group while the group is also influenced by the leader.

Leadership researcher conceptualize leader emergence in one of two ways. The trait approach to leadership views inherent personality factors as antecedents to leadership (Bass, 1990; Judge & Bono, 2000; Northouse, 2007). Interest in the trait approach to leadership has resulted in the development of various leadership characteristics (Kirkpatrick & Locke, 1991; Jago, 1982; Stogdill, 1948). Five factor personality models have led to frameworks for describing leadership antecendents

(Digman, 1990; Goldberg, 1990; Judge, Bono, Ilies, & Gerhardt, 2002). Contingency approaches to leadership suggest that environmental conditions combined with leader behavoirs, determine leader effectiveness (Judge & Robbins, 2007). Contingency theories have led to many leadership models which describe, prescribe, or predict leadership behaviors and performance within well defined environmental conditions (Bowers & Seashore, 1966; Hersey & Blanchard, 1982; House, 1971; Bass, Avolio, Jung, & Berson, 2003). Both approaches rely on a linear construct where leaders' actions affect followers' actions in some specific way (Yukl, 1989). Because leader emergence involves the actions of the group as well as the leader, complexity theory can assist in describing leader emergence as a non-linear interdependent group dynamic (Marion & Uhl-Bien, 2001).

Although leader emergence has long been established as a reciprocal process (Bass, 1990), empirical research is only beginning to implement methods for modeling the non-linearity behind group interactions (Hazy, 2007). As Dooley (1997) notes, our understanding of leader emergence will always coincide with the methods used to explain it. As such, longitudinal research has been harkened as the harbinger of a wider spectrum of methodologies to leadership research (Hunt & Ropo, 2003). The influence of complexity science has refined the notion of leader emergence within a CAS (Marion & Uhl-Bien, 2001), as well as the role of leadership within a CAS (Plowman, Solansky, Beck, Baker, Kulkarni, & Villareal Travis, 2007; Uhl-Bien, Marion, & McKelvey, 2007). Missing from leadership research is a model of leader emergence accounting for the reciprocal interaction between an individual's initial leadership disposition, situational factors, and CAS dynamics. Longitudinal social network analysis is one technique to record the reciprocal interactions within a CAS which precede leader emergence.

Social Network Analysis as a Measure of CAS Behavior

Interactional methods of social network analysis record the flow of interactions between group members. The flow of interactions has indications on the influence of power (Tichy, Tushman, & Fombrun, 1979). Every individual in a group is a node, and the interaction between a pair of nodes is an arc. Arcs can have direction, indicating with whom each actor perceives they do or do not interact. Networks can be examined based on the type of interactions. Task networks analyze the flow of work related information and tasks across a group, while affect networks capture the flow of friendship or social ties across a group. Using social network analysis, all individual interactions can be placed into a matrix, and mathematical techniques can be used to precisely determine different network measures. The development of centrality measures has been a useful tool for describing location within, and influence over the group (Costenbader & Valente, 2003).

Degree centrality measures the number of interactions that a particular actor receives or extends. In-degree centrality measures the number of requests for interaction the actor receives, while out-degree centrality measures the number of requests for interaction the actor extends (Wasserman & Faust, 1994). Out-degree centrality, being a reflection of self-reported network ties (Costenbader & Valente, 2003), may show different longitudinal behaviors than in-degree or betweenness centrality. Correlation research has found a positive relationship between task network in-degree centrality and individual performance (Sparrrowe, Liden, Wayne, & Kraimer, 2001; Ahuja, Galletta, & Carley, 2003), while other studies have shown a relationship between academic performance and leader selection (Schneider, Holcombe Ehrhart, & Ehrhart, 2002). It is plausible that a relationship exists where academic performance increases in-degree selection which may impact leader emergence. While degree centralities measure the volume of interactions, betweenness centrality focuses on the strategic location of a specific actor within a network structure.

Betweenness centrality has been empirically found to measure which actor within a group was most often viewed as a leader (Mullen, Johnson, & Salas, 1991). Betweenness centrality measures the proportion of geodesics in which an actor is a link (Wasserman & Faust, 1994). A geodesic is the shortest path between two actors. The calculation for a geodesic can become complicated in a directed network where the path from node N_j to actor N_i is not the converse of the path from N_i to N_j. One's predisposition for betweenness centrality may be personality based (Mehra, Kilduff, & Brass, 2001), but some studies suggest that cognition of social networks may play a key role in leader emergence (Balkundi & Martin, 2006), indicating that betweenness centrality may be a careful selection on the part of the potential leaders. The ability to gain a between central location may be a result of the interaction choices within the network. To understand the network choices, analyzing both betweenness and degree centralities may provide a useful means for understanding variations between longitudinal behaviors of leaders versus followers.

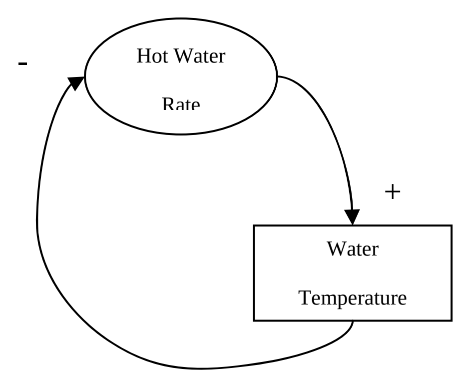
Centrality measures can be represented numerically, higher centrality scores correspond with being more central (Wasserman & Faust, 1994). The time-series analysis of centrality measures may then result in characteristic longitudinal behaviors. Tracking different network centrality measures provides depth to the longitudinal data collected, and may reveal behaviors for which system dynamics can provide insight. The use of longitudinal social network analysis to record CAS behaviors, combined with the analytical methodology of system dynamics, is a logical tool for understanding the dynamics of leader emergence.

System Dynamics

Understanding a social system, a system being a grouping of parts that work together for a common purpose (Forrester, Priciples of Systems, 1968), will require techniques of understanding non-linearity created by the reciprocal relationships between what social sciences call independent and dependent variables (Forrester, 1987). The extant leadership literature is based on the notion of an open system, one in which a predictor, or independent variable, causes changes in a criterion, or dependent variable (Patten, 2005). While this method has been instrumental to the development of leadership theories, relationships between variables in natural social systems may interact as a closed system. In a closed system perspective, the independent variable causes change in the dependent variable, which in turn causes change in the original independent variable. System Dynamics is a method to reveal and test interrelations within a closed system through modeling and simulation (Sterman, 2000). Applying system dynamics to known behaviors within a CAS will allow testing of leader emergence theories, and predictions based on the system structure, or theory of the overall system.

System dynamics defines problems with two basic variables. The first of the two basic variables is the stock, the true level or state of the system. The second variable is the flow, the rate of items accumulating in the stock. These two variables can be arranged to create open or closed systems. In a closed system, these variables construct the basic element known as a feedback loop. Feedback loops create non-linear behaviors which can be difficult to conceptualize when trying to understand real-world phenomenon (Forrester, 1968). Understanding the nature of negative and positive feedback loops facilitates the conceptualization of real world events and represents the foundation of understanding system dynamics.

Feedback in organizational behavior parlance is simply the reaction to a particular activity. The true essence of feedback is that it is used to adjust the performance of further activity. In system dynamics, a feedback loop is used to describe closed systems (Forrester, 1968). Feedback loops come in two forms. Negative feedback loops seek a goal and constantly adjust to meet the goal. A simple analogy of a negative feedback loop is the system one employs to regulate the temperature of the water in a shower. After turning the hot water



Negative Feedback Loop

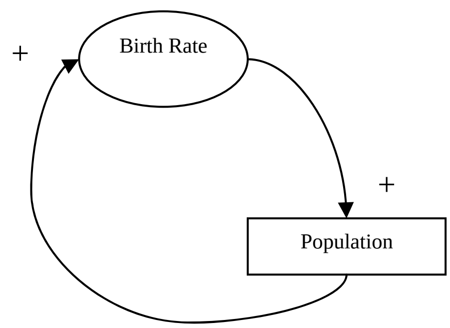
Figure II-1

faucet on full blast to get the hot water flowing, you prepare to enter. What was changed, the independent variable, is the flow or rate at which the hot water is flowing through the pipes. The impact this has, the dependent variable, is the temperature of the shower. As you enter the shower and adjust the water to sub-scalding levels, you decrease and increase the flow of hot and cold water to regulate the “stock” or level of the temperature until the desired goal is met. In this way, the level of the temperature influences the decision to increase or decrease the flow of hot water. The negative feedback loop is illustrated in Negative Feedback Loop

Figure II-1, where a circle is used to represent a flow, and a square to represent a stock. The positive sign indicates that as the hot water rate increases, the water temperature increases. The negative sign indicates that as the water temperature increases, the decision is made by the individual to decrease the hot water flow. The product of the positive and negative signs result in an overall negative loop, hence the term “negative” or “compensating” feedback loop (Sterman, 2000; Forrester, 1968; Shelley, 2007).

The second form is a positive feedback loop, which generates growth through action causing yet greater action. A simple example of a positive feedback loop is population growth. As a couple gives birth to multiple children, the population increases. As the population increases, the number of new children being born increases. Here, the independent variable is the flow, or rate, at which couples have children. The dependent variable is the stock, or level, of people in the world. This unchecked population growth is an example of a positive feedback loop, illustrated in Positive Feedback Loop

Figure II-2.



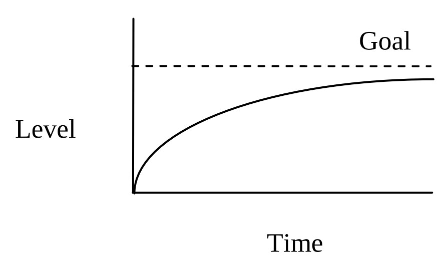
Positive Feedback Loop

Figure II-2

The positive signs indicate that as the rate of births increases, the level of population increases, and as the stock of population increases, the flow of births increases. The product of the signs in the diagram results in an overall "positive" or "reinforcing" feedback loop (Sterman, 2000; Forrester, 1968; Shelley, 2007).

Systems are not composed of isolated feedback loops. A system will contain an unknown number of feedback loops. The coupling of many feedback loops result in a dynamic behavior which can be graphed over time. The graph of system behavior over time is known as the reference mode diagram, and its general trend gives indications as to the structure of the system. The general reference mode behavior of a negative feedback loop is given in Negative Feedback Loop Reference Mode Diagram

Figure II-3. Here, the level starts below the final goal and quickly



Negative Feedback Loop Reference Mode Diagram

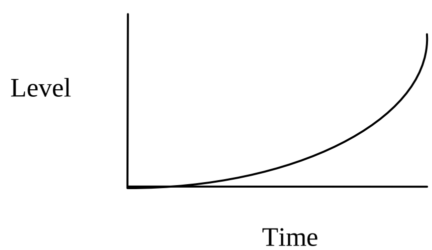
Figure II-3

approaches it. There are several basic structures which constitute negative feedback loops. In other words, there is more than one way to arrange stocks and flows to generate the behavior shown. Subtle differences in the nature of the reference modes are insightful in developing the system dynamic model. A positive feedback loop has a distinct curvature as well. The general form of the reinforcing reference mode behavior is given in Reinforcing Exponential Growth Reference Mode

Figure II- and Reinforcing Exponential Decay Reference Mode

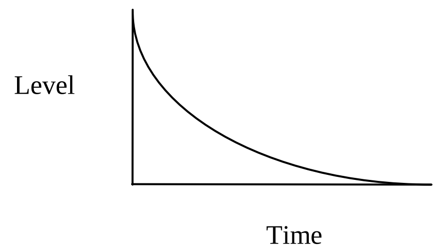
Figure II-. The general curve demonstrates the positive loop's tendency to grow or deplete at exponential rates. The arrangement of compensating and reinforcing loops result in a finite number of structures with which system dynamic models can be understood and formulated (Sterman, 2000). Causal diagrams illustrate the arrangement of stock and flow loops based on longitudinal reference mode behaviors. Appendix A lists 14 rudimentary reference mode diagrams with their corresponding causal diagrams (Shelley, 2007).

Comparing longitudinal data to reference mode behaviors in the table in Appendix A allows one to develop causal diagrams. Causal diagrams allows for the



Reinforcing Exponential Growth Reference Mode

Figure II-4



Reinforcing Exponential Decay Reference Mode

Figure II-5

diagrammatically describing the non-linear relationships between variables (Forrester, 1968; Sterman, 2000; Shelley, 2007). Using software such as STELLA, the mathematical equations involved in the system can be used for computer simulation, prediction, system understanding and policy development. This raises the question: What longitudinal data needs to be collected to enhance the non-linear understanding of leader emergence?

The recent focus on CASs suggests that longitudinal social network analysis may provide insight into leader emergence. Correlation analysis can relate dynamic measures, such as centrality and performance, with attributes considered static, such as personality and peer leader nominations. These measures and attributes may be interrelated in such ways that system dynamic analysis of longitudinal data can reformulate the way leader emergence is conceptualized.

Static Measures

While individual performance is traditionally considered a static measure, it has been shown to correlate with personal attributes and dynamic measures. Performance has been strongly correlated with goal setting (Locke, Shaw, Saari, & Latham, 1980), and goal setting has been correlated with measures of self-efficacy (Zimmerman, Bandura, & Martinez-Pons, 1992). Studies of student performance suggest that self-efficacy (Zimmerman, 2000), student involvement (Ullah & Wilson, 2007; Paas, Tuovinen, Van Marrienboer, & Darabi, 2005), and more importantly study environment (Gupta, Harris, Carrier, & Caron, 2006; Plant, Ericsson, Hill, & Asberg, 2005) predict academic success. One's academic success may rely on the rate of time spent studying, as well as the efficiency (amount learned per time spent studying) of the individual. The significance of efficiency is that the more academically efficient an individual, the more time available for network interaction while achieving academic success. While academic performance has merit for predicting leader emergence (Kellett, Humphrey, & Sleeth, 2002), Mehra et al. (2001) demonstrated that work place performance was predicted by self-monitoring and network centrality.

Self-monitoring is the tendency of an individual to regulate their behavior toward social appropriateness. Self-monitoring has been correlated with betweenness centrality (Moore, 2006; Mehra, Kilduff, & Brass, 2001) and the number of incoming friendship relations (Sassova, 2006), or affect network in-degree centrality. Because betweenness centrality has been demonstrated to strongly correlate with leader emergence (Wasserman & Faust, 1994; Mullen, Johnson, & Salas, 1991), the tie between self-monitoring and betweenness centrality may be of interest. Another group of factors which have been correlated with leadership come from the big five personality measure.

The big five factor structure distills personality attributes into five distinct characteristics: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness (Goldberg, 1990). When applied to leadership research, extraversion has been shown to consistently predict leader emergence and effectiveness (Judge, Bono, Ilies, & Gerhardt, 2002). In terms of social network behavior, extraversion and low neuroticism have been found to be linked to triads of strong ties (Kalish & Robins, 2006). Longitudinal personality research suggests that the five factor traits show sufficient continuity over time (Robins, Fraley, Roberts, & Trzesniewski, 2001) that for our purposes (leader emergence over an eight week period) we can consider these measures static. While personality impacts the way an individual addresses and interprets information from the world around them, satisfaction has been found to correlate with the way the individual responds to others in the environment.

Work Group Satisfaction

A work group is a plural number of people primarily sharing information and making decisions interdependently to assist each member perform within their respective areas of responsibility (Judge & Robbins, 2007). Workgroup satisfaction has demonstrated a positive relationship with the successful leadership of immediate supervisors (Rowland & Scott, 1968). Workgroup satisfaction has also been found to support workgroup outcomes by facilitating group interaction (Nguyen, Seers, & Hartman, 2008) especially among work groups rather than larger organization as a whole (Riketta & Van Dick, 2005). The implication is that workgroup satisfaction may provide a link between group performance and the effectiveness of an emergent leader. Since the system dynamics paradigm requires an exploration of potential feedback, including explicit reactions from each individual within the CAS may prove beneficial.

Summary

As the system dynamic model is developed, an iterative process will refine the model to understand the interdependent nature of the data collected. The final goal is to understand leader emergence in a way that indicates interrelatedness with several antecedents. CAS dynamics recorded through the use of longitudinal research will provide the opportunity for system dynamic analysis. The extant leadership and organizational behavior research will lend valuable support in understanding the nature of information collected. Ultimately, the goal of this thesis is to answer the question: Can the process of leader emergence be accurately modeled using common leader emergence predictors using System Dynamics?

III. Methodology

Sample

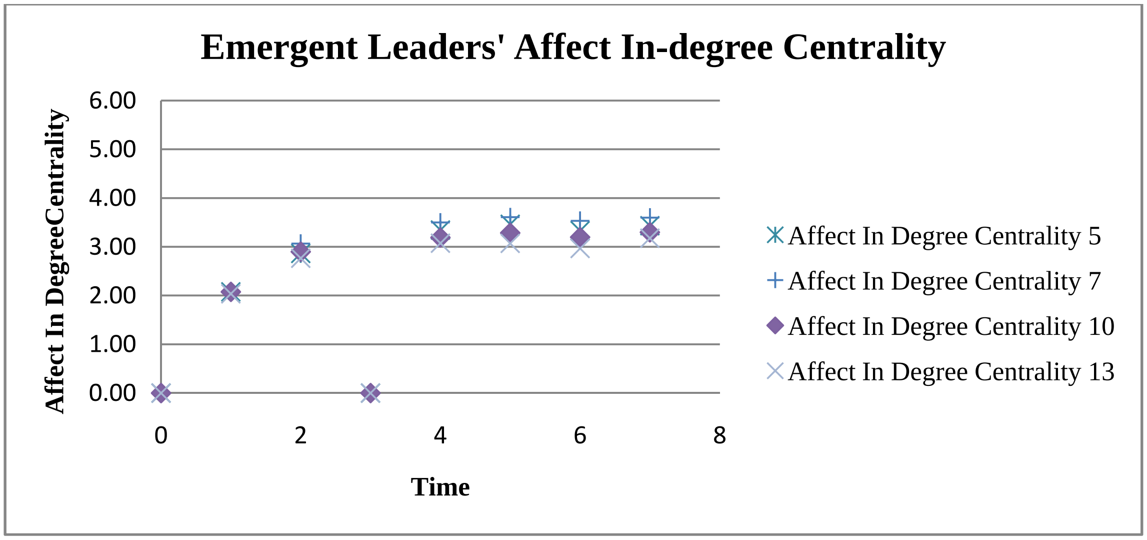
The data was obtained from students attending a seven week leadership development course intended to prepare senior enlisted military personnel for increased leadership and management responsibilities. The population studied consisted of 28 groups of approximately 12-16 students. Efforts are made at the school to ensure diversity among groups, or flights, by evenly distributing students along gender, race, career field, and home station location criteria. The population consisted of 406 students led by instructors.

Social Network Measures

The social networks were differentiated by asking different sets of questions. Task and affect network each had two questions. Task network questions asked how much time is spent on work related tasks with each individual, or how often each individual is sought out for work oriented advice. Affect network questions similarly asked how much time is spent in socially oriented activities with each member, and how much time is spent "hanging out" with each member. Responses ranged from a low of 1 to a high of 5 for each question. The survey was administered seven times during the eight week period, due to one period during week 3 of the course where the population was unavailable due to a field leadership exercise.

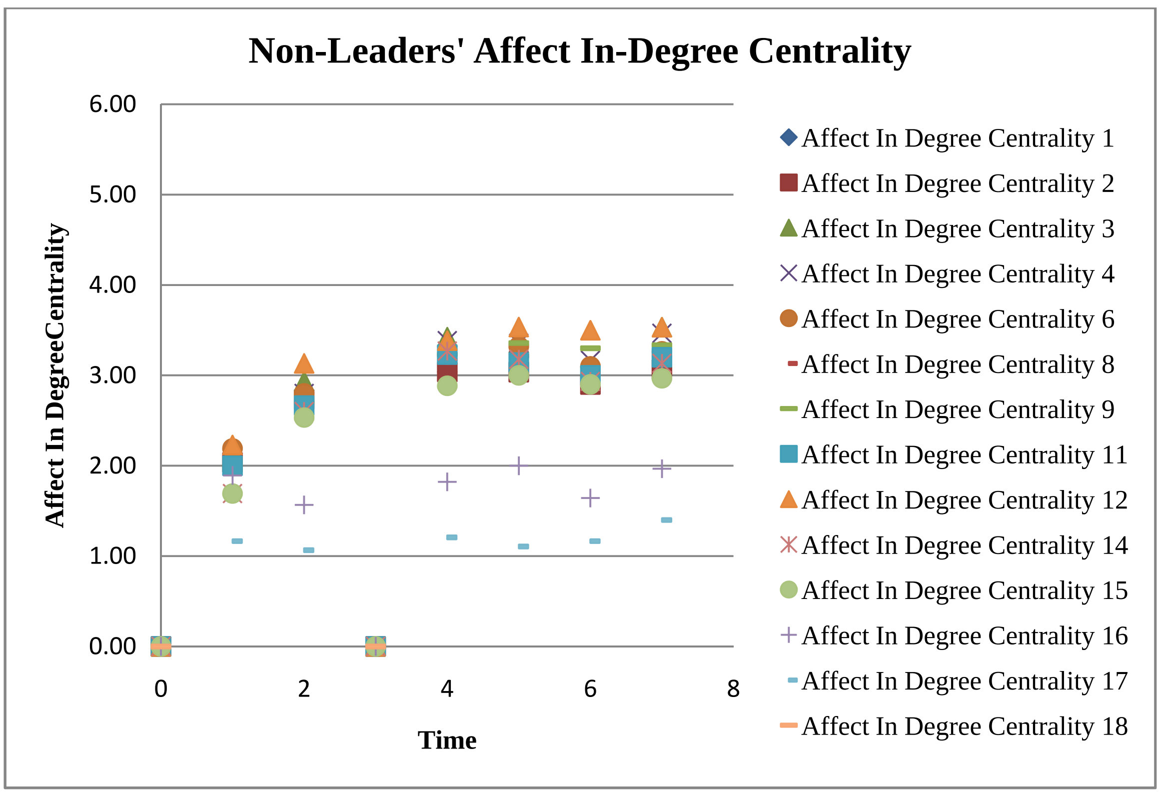
Longitudinal Group Measures

In-degree centrality represents the aggregate response of the group to the individual. Wasserman and Faust (1994) note that in-degree centrality measures the cumulative proportion of requests for interaction a particular actor receives from the whole group. While the quantity of in-degrees differs between leaders and non-leaders, the trend did not. Degree centralities were plotted for each individual within each group. Separate plots were made based on the threshold of peer leadership points scored. One graph represented those individuals who received the majority of peer leadership points, while the other graph showed all others in the group. Figure III-1 and Figure III-2 show the longitudinal results of the affect in-degree centrality of group members and the difference between leaders selected by the group, versus those not selected as leaders. The general trend shows no difference in the longitudinal behavior from which it can be ascertained that the affect in-degree centrality follows a negative feedback loop. Appendix A lists four possible causal diagrams which fit the behavior observed. Figure III-3, Figure III-4, Figure III-5, and Figure III-6 apply the general causal diagrams to the affect in-degree construct. While other factors may cause the in-degree centrality to fluctuate, the general curve is consistent across all groups studied. The consistency of the behavior suggests there is a natural behavior described by one of the four compensating structures.



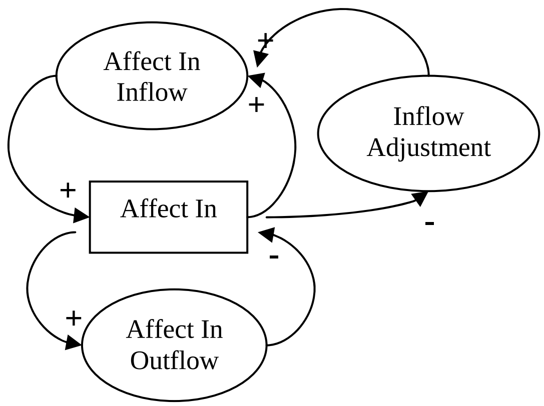
Emergent Leaders' Affect Network In-degree Centrality

Figure III-1



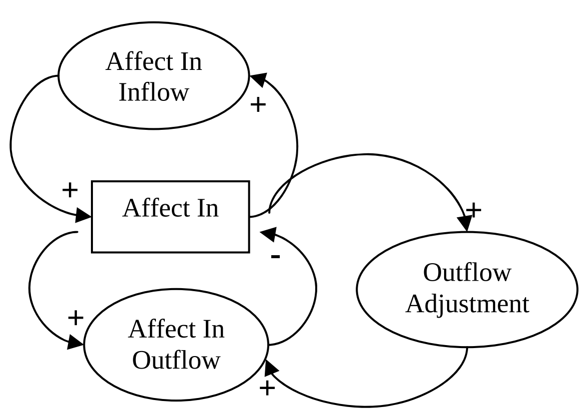
Non-Leaders' Affect Network In-Degree Centrality

Figure III-2



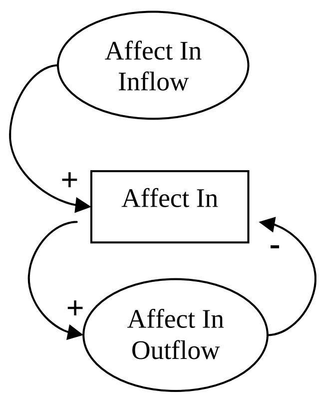
Gradual Growth S-Shaped

Figure III-3



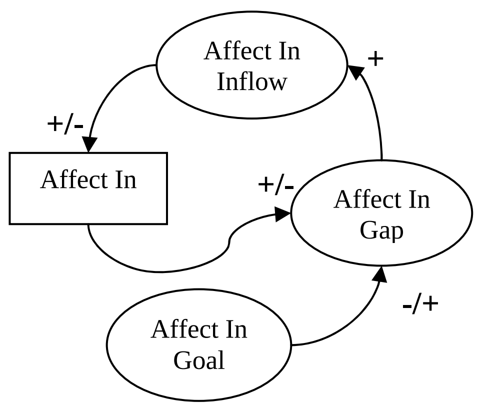
Exponential Growth S-Shaped

Figure III-4



Approach to Steady State

Figure III-5

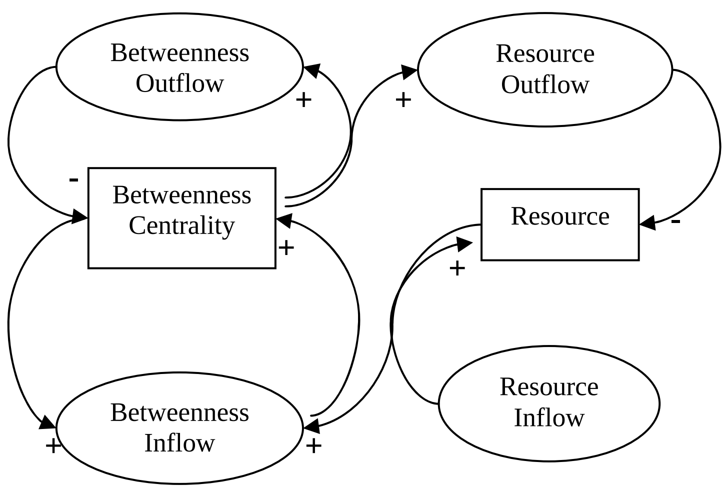


Goal Seeking Curve

Figure III-6

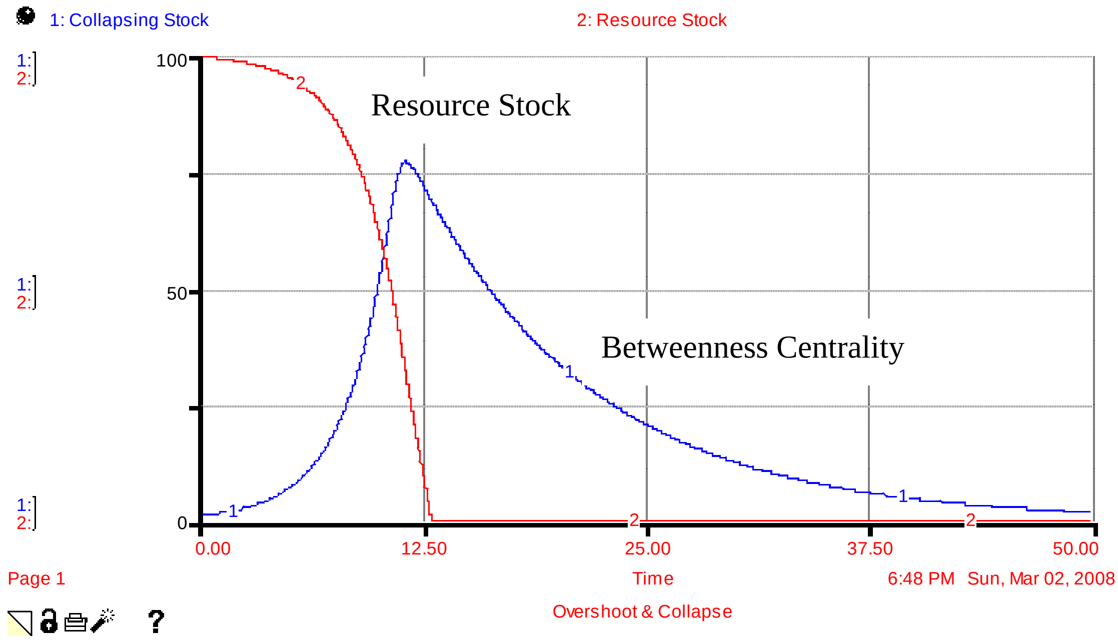
Task in-degree centrality followed the same general curve, so the same possible causal diagrams would describe task in-degree centrality, however the words “Affect In” would be replaced with “Task In”.

Betweenness centrality demonstrates a unique behavior. While the peak at time two is not a trademark of all leaders, it is consistent among high self-monitors (Moore, 2006). The initial peak then tapering observed is typical of the "Overshoot and Collapse" reference mode from Appendix A. The corresponding causal diagram is shown in Figure III-7. The resource stock is left for determination in the iterative process of building the system dynamic model. In time, the resource stock is depleted as a consequence of the rise in betweenness centrality. The reference mode diagram in Figure III-8 illustrates the rise and fall of each stock. Line 1 in the reference mode diagram is the stock which follows the overshoot and collapse behavior, while line two is the resource that is depleted as a result.



Overshoot and Collapse

Figure III-7

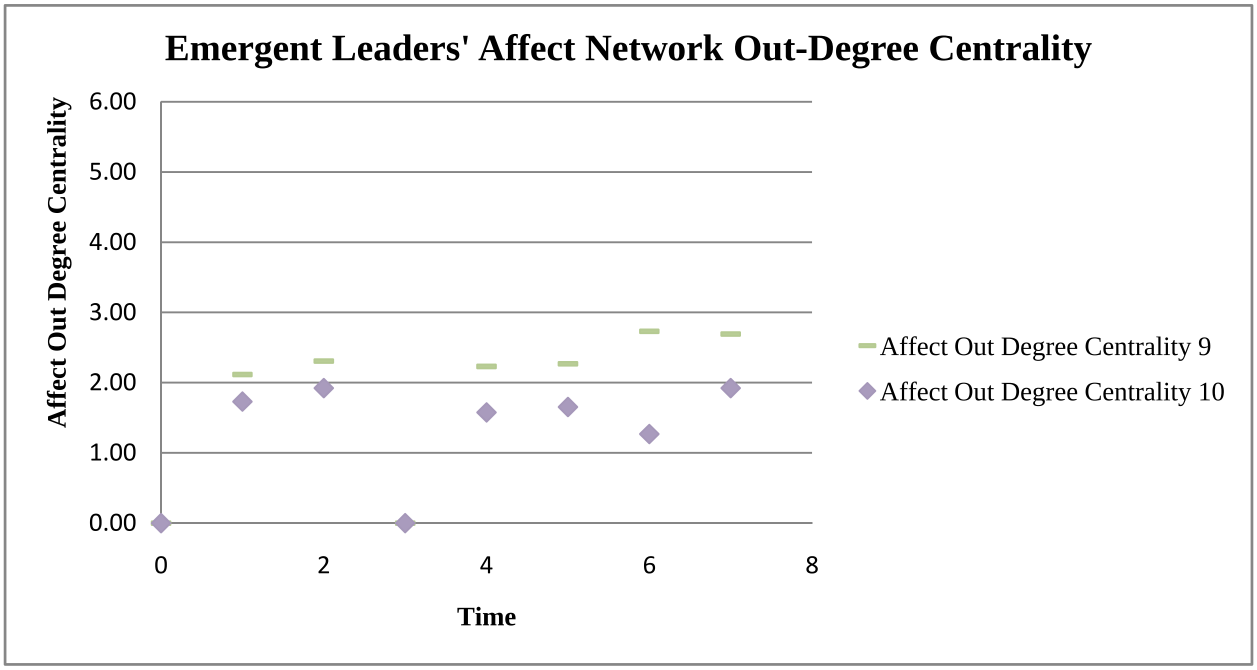


Overshoot and Collapse Reference Mode Diagram

Figure III-8

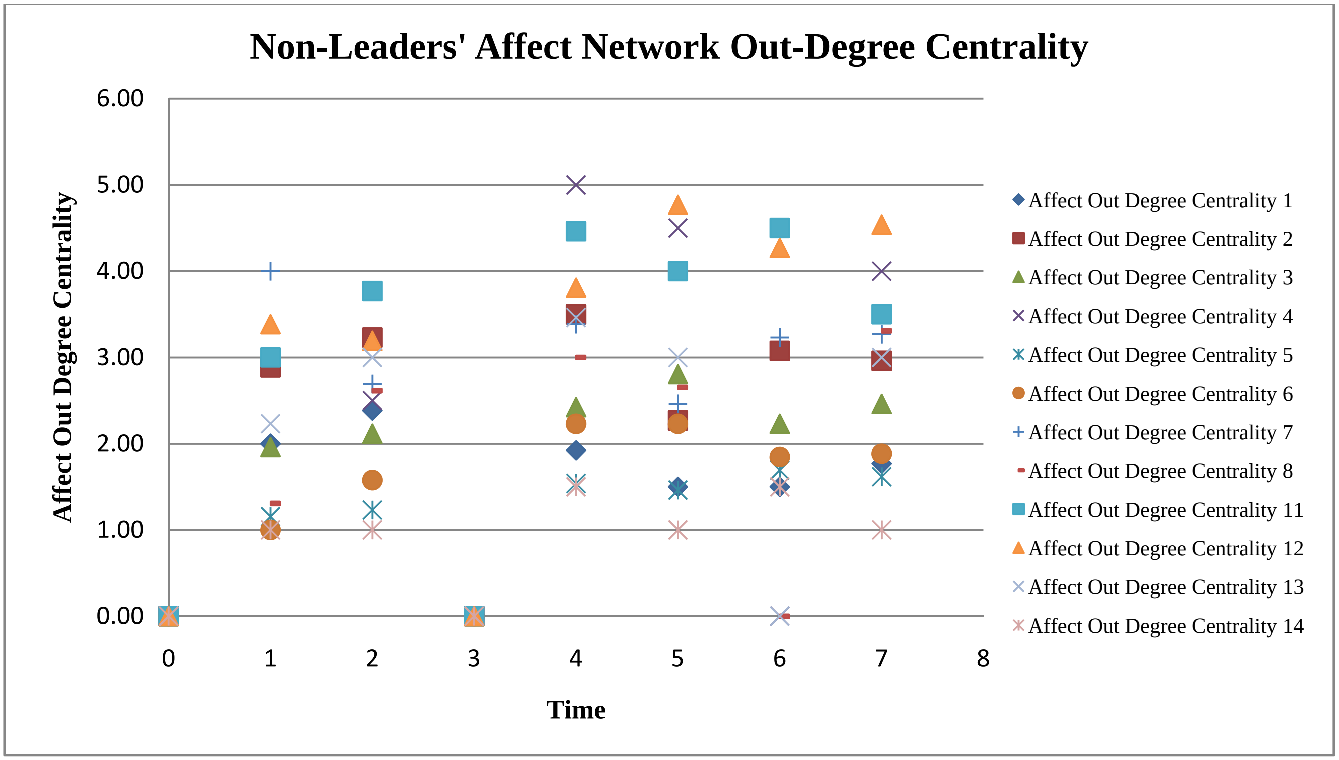
Individual Longitudinal Behaviors

Out-degree centrality reflects the interaction decisions of the individual (Wasserman & Faust, 1994). It stands to reason that longitudinal affect network out-degree centrality behavior for leaders may differ from that of non-leaders. Figure III-9 and Figure III-10 show the affect network out-degree centralities for emergent leaders and non-leaders respectively. The longitudinal graphs show the general shape of a compensating loop. In the graphs provided here, the emergent leaders' affect network out-degree centrality is in general,



Emergent Leaders' Affect Network Out-Degree Centrality

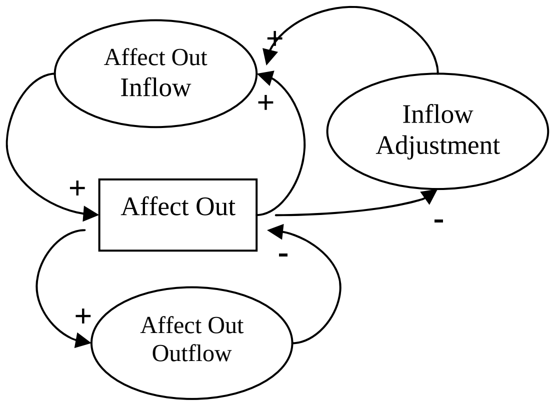
Figure III-9



Non-Leaders' Affect Network Out-Degree Centrality

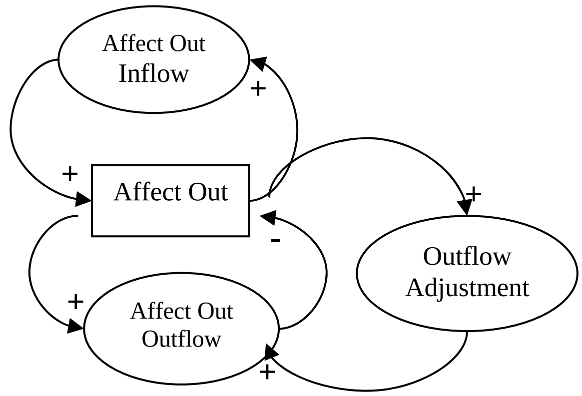
Figure III-10

lower than the group average, but the trend indicates it is of the same nature as it is for all actors in the group. The possible causal diagrams are shown in Figure III-11, Figure III-12, Figure III-13, and Figure III-14.



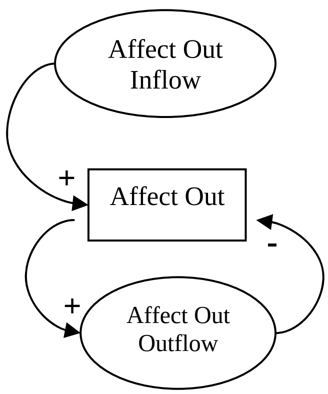
Gradual Growth S-Shaped

Figure III-11



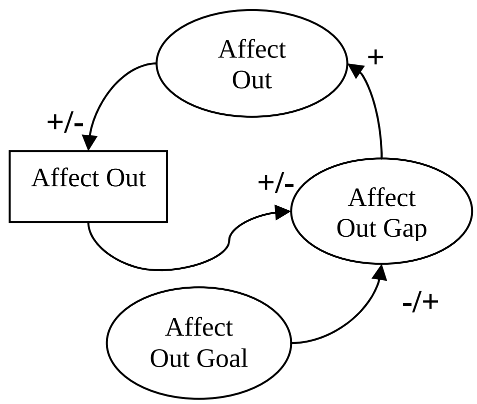
Exponential Growth S-Shaped

Figure III-12



Approach to Steady State

Figure III-13

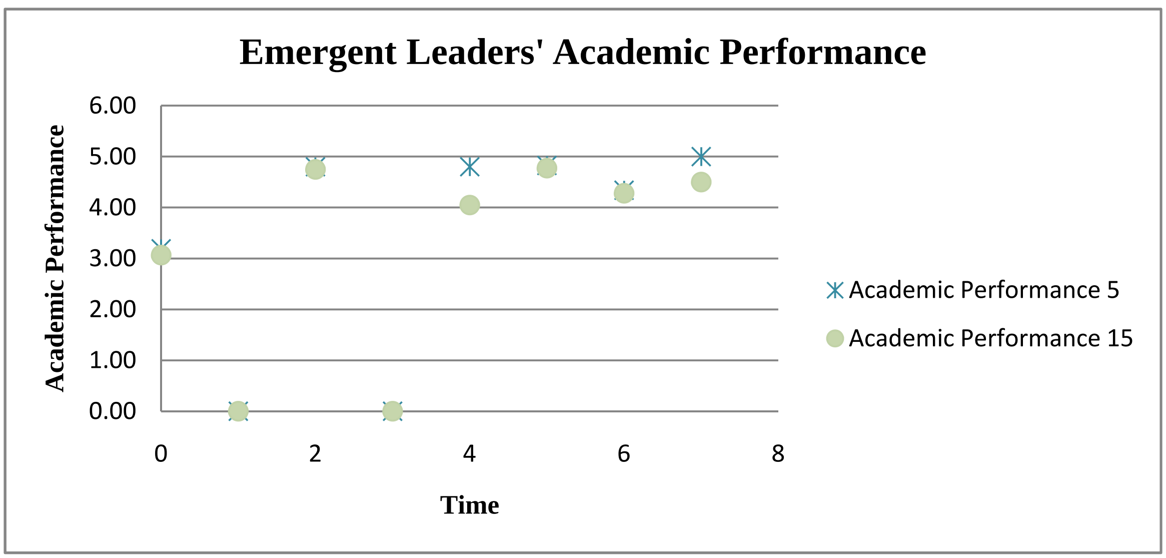


Goal Seeking Curve

Figure III-14

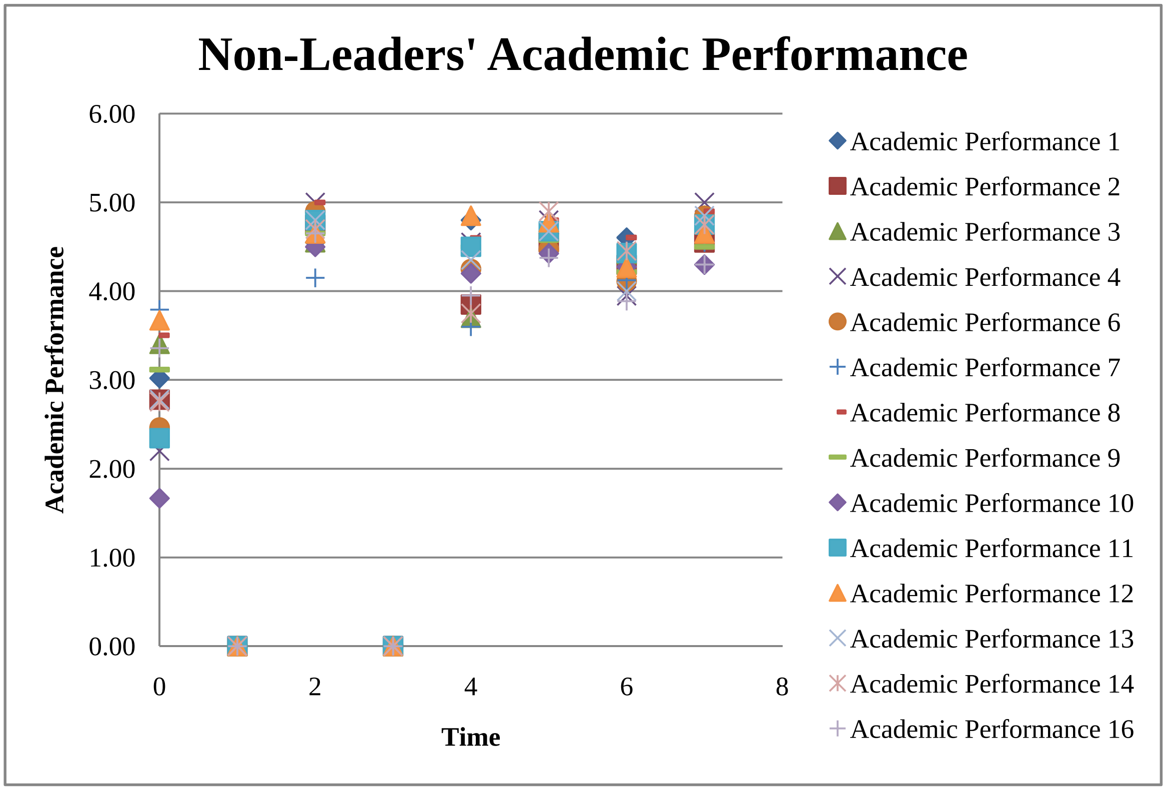
Academic Performance

The longitudinal academic performance behavior of emergent leaders and non-leaders did not differ remarkably in the course of the eight week study, and displayed a typical compensating loop reference mode behavior, as shown in Figure III-15 and Figure III-16. Goal setting theory offers a suggestion that the goal setting causal diagram may be responsible for this longitudinal behavior (Locke, Shaw, Saari, & Latham, 1980). Academic scores include an initial written test, various speeches, papers, and additional comprehensive tests on course material. Academic scores were scaled to range from zero to five.



Emergent Leaders' Academic Performance scaled to range from zero to five

Figure III-15



Non-Leaders' Academic Performance scaled to range from zero to five

Figure III-16

Work Group Satisfaction

Work group satisfaction was measured using a seven point scale with an emotional representation to rate an individual's response to the group interactions. Items included consideration of sentiment toward flight mates, the level of interaction, the flow of information and the amount of influence one has on the rest of the work group. Seven was the most content, while one represented the highest frustration. Work group satisfaction was measured at seven time periods throughout the duration of the course. The scores were scaled to range from one to five for comparative reasons in the longitudinal analysis. While the work group satisfaction typically dipped after the first week, it then reached some level which indicates its natural behavior is in the form of a negative feedback loop.

Static Personality Attribute Measures

Several personality measures were collected which have been empirically shown in leadership research literature to correlate with leadership. The big five factor personality traits were examined using 65 adjectives correlating with the five categories of personality. SPSS was used to verify an average reliability of .892.

Another personality factor of interest was self-monitoring. Self-monitoring was recorded using an 18 item true or false instrument with statements reflecting different degrees of self monitoring behaviors. SPSS was used to verify the reliability of the self-monitoring questionnaire which resulted in an alpha of .719.

Instructors were required to rate each student by partitioning 45 leadership points in five point increments based on their assessment of an individual's leadership ability. Peers were required to rank order their flight mates' leadership. The top ranked individuals received a Peer A score, worth 5 points per Peer A selection. Second highest ranked leaders received a Peer B score, were worth 3 points per Peer B selection. Finally, third highest ranked leaders received a Peer C score, worth 1 point per Peer C selection.

All measures were checked for correlations to identify which factors influenced other factors. This process was used to trim down the amount of factors considered important in the system dynamic model, and help to reduce the scope of the model. The final result was an SPSS output that ran 112 pages long. The statistical correlation agreed with leadership research. The following is a summary of the findings which ends with a table of correlations (Table III-1) between static measures and leadership selection, a graphical representation of the correlations between longitudinal measures (Figure III-17), and a graphical representation of personality measures correlated with longitudinal measures(Figure III-18).

First all static measures were correlated with leadership scores. Instructor Leadership Points were correlated with high academic scores from time periods two through seven, extraversion, self monitoring, positive affect, and Peer A, B and C points. Peer A points were positively correlated across all betweenness centrality scores, affect network in-degree centrality for time periods two through seven, academic scores for time periods two through seven, self-monitoring, and instructor as well as Peer B, and C leadership points. Peer B leadership scores were correlated with academic performance, extraversion, openness to experience, self-monitoring, and Peer C leadership points. Peer C leadership points were correlated with affect network in-degree centrality, academic scores, extraversion, and emotional stability (low levels of neuroticism). Neuroticism was found to be negatively correlated with workgroup satisfaction, positive affect, conscientiousness, agreeableness and extraversion, and positively correlated with negative affect. Extraversion was found to be correlated with betweenness, at the middle and end of the study period, affect network out-degree centralities in the middle of the 8 week period, task network out-degree centrality, work group satisfaction, positive affect, self-monitoring, conscientiousness, and openness to experience. Openness to experience was negatively correlated with affect network in-degree during weeks four though six of the eight week period, and positively correlated with workgroup satisfaction during the first 3 weeks, positive affect, self-monitoring, conscientiousness, and agreeableness. Agreeableness was correlated with workgroup satisfaction, negatively correlated with the 6^{th} academic score, but positively correlated with the 7^{th}, and positively correlated with positive affect and conscientiousness. Conscientiousness was negatively correlated with betweenness centrality in the fourth week, affect network out-degree in the second week, and negative affect, and positively correlated with workgroup satisfaction, the initial academic score, and positive affect. Self-monitoring was correlated with second and fourth week of betweenness centrality, second through sixth week of affect network out-degree centrality, fourth through sixth weeks of task network out-degree centrality, slightly with workgroup satisfaction in all but the sixth week, academic score in the second and fifth weeks, positive affect, and negatively correlated with negative affect. Positive affect was correlated with betweenness centrality in the second and sixth weeks, affect network out-degree centrality, task network in-degree in weeks two through six, task network out-degree centrality, workgroup satisfaction, and negatively correlated with academic score in the sixth week as well as negative affect. Negative affect was negatively correlated with workgroup satisfaction. Table III-1 is the SPSS output which is summarized above.

SPSS Correlation analysis output for Personality factors and Leader Selection Points

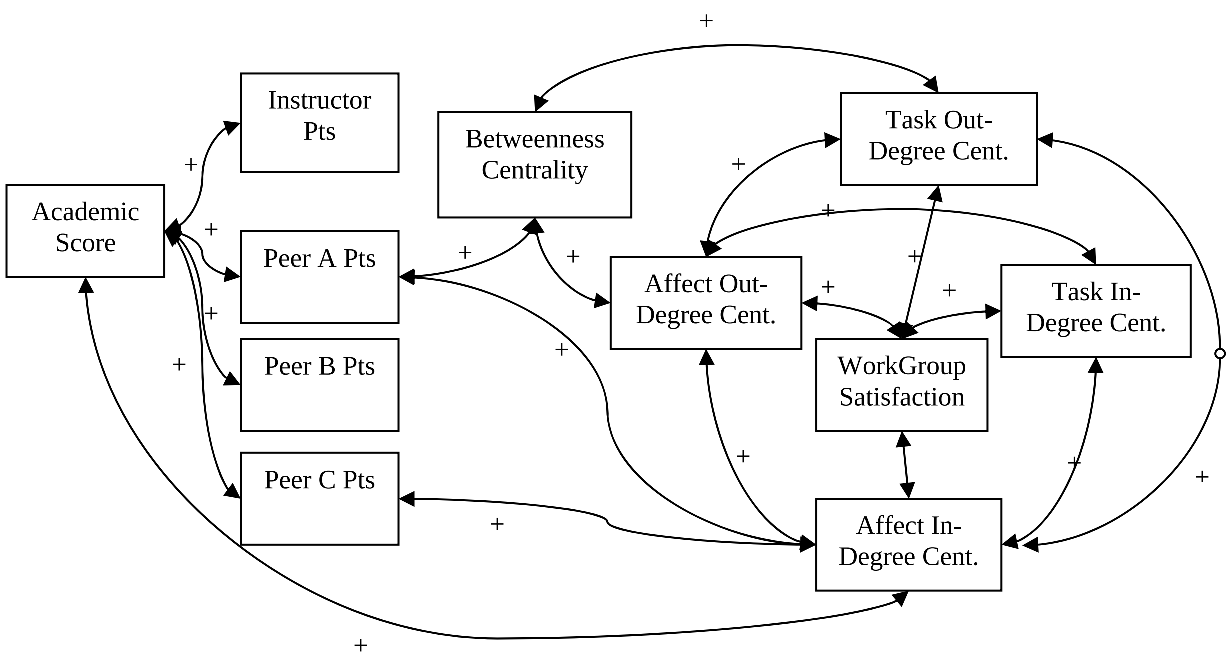
Table III-1

	N	E	O	A	C	PA	NA	SM	LoC	InstPts	PeerAPts	PeerBPts	PeerCPts
N	1	-.217(**)	-.033	-.338(**)	-.162(**)	-.226(**)	.286(**)	-.094	-.138(**)	-.068	-.076	-.057	-.104(*)
E		1	.305(**)	.035	.138(**)	.354(**)	-.302(**)	.418(**)	.165(**)	.128(*)	.081	.139(**)	.106(*)
O			1	.189(**)	.287(**)	.210(**)	-.123(*)	.263(**)	.075	.065	.048	.111(*)	.009
A				1	.444(**)	.254(**)	-.111(*)	.043	.056	.031	-.017	.015	.035
C					1	.269(**)	-.126(*)	-.064	.070	-.007	.021	.098	.041
PA						1	-.232(**)	.115(*)	.184(**)	.113(*)	.078	-.030	.068
NA							1	-.121(*)	-.221(**)	-.059	-.075	-.035	-.048
SM								1	.019	.146(**)	.160(**)	.188(**)	.039
LoC									1	.027	.063	-.011	.130(**)
InstPts										1	.447(**)	.273(**)	.249(**)
PeerAPts											1	.319(**)	.263(**)
PeerBPts												1	.214(**)
PeerCPts													1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Correlations were used to identify structures that are linked with leader emergence, as well as dynamic measures that may be interdependent. Checking dynamic elements for correlation revealed the following results. Academic scores were correlated with affect network in-degree centrality. High workgroup satisfaction scores were correlated with affect network in-degree centrality, affect network out-degree centrality, task network in-degree centrality, and task network out-degree centrality. Task network out-degree centrality was correlated with affect network betweenness centrality; affect network in-degree centrality time periods two through six, affect network out-degree centrality, task network in-degree centrality. Task network in-degree centrality was found to be correlated to affect network in-degree centrality, and affect network out-degree centrality. Affect network out-degree centrality was found to be correlated with betweenness centrality, and affect network in-degree centrality. Finally, Affect network in-degree centrality was found to be slightly correlated with betweenness centrality.

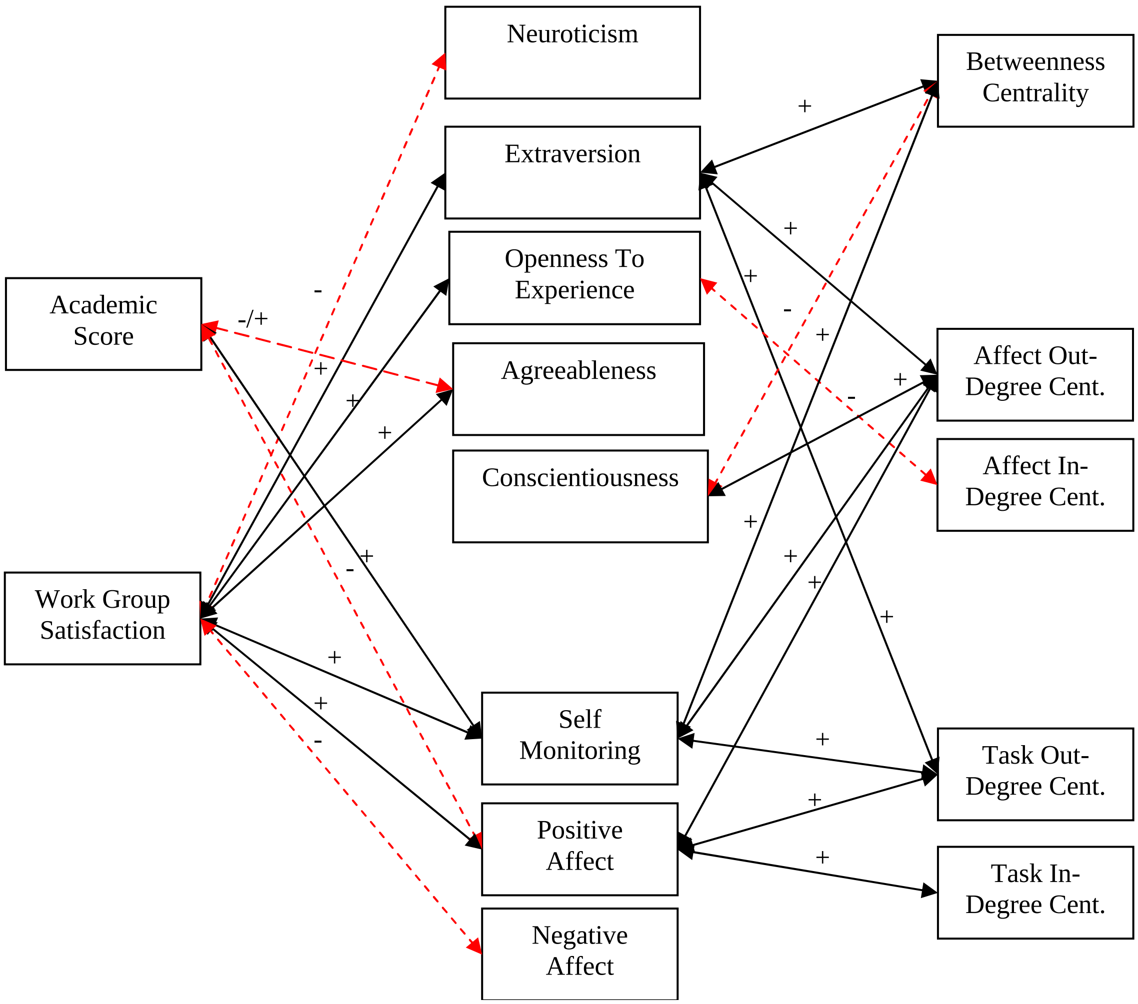
Correlations identified within dynamic factors, as well as across static measures, provided empirical support for reducing the scope of the system dynamics model. In terms of leader emergence, the crucial dynamic measures were academic score, betweenness centrality, and affect in-degree centrality. In terms of interdependencies between dynamic factors, academic scores, affect network in-degree centrality, and betweenness centrality influences and/or are influenced by task network out-degree, task network in-degree, affect network out-degree, and task network in-degree centralities. Workgroup satisfaction was found to be correlated with all personality traits except conscientiousness, and all longitudinal measures except betweenness centrality and academic score. Workgroup satisfaction did not however correlate directly with leadership scores. Figure III-17 summarizes the interrelatedness. The direction of influence will be determined in the analysis.



Graphical summary of correlations among longitudinal data and Leadership points

Figure III-17

Personality measures correlated strongly with the various longitudinal measures, but the majority correlated strongly with workgroup satisfaction. The potential interdependencies between each personality measure and longitudinal factors are represented in Figure III-18   From this, it was determined that extraversion, and self-monitoring have strong influences on betweenness and out-degree centralities which in turn influence leader emergence. The final iteration of the system dynamics model focused on these relationships.



Graphical summary of correlations between personality factors and longitudinal data

(Dashed lines indicate negative correlation)

Figure III-18

IV. Results

Chapter Overview

This chapter will briefly cover the initial attempts at developing the system dynamic models and discuss insight gained. The remainder of the chapter will cover the development of the final model. Additional literature was reviewed in the final iteration of the model. Conclusions drawn from the additional research contributed to the understanding of leader emergence.

Initial System Dynamic Models

System dynamics uses an iterative process to arrive at system solutions (Forrester, 1992). This model involved several iterations, but the development of the final model occurred with the development of the following set of models.

The initial model relied heavily on the longitudinal data and the statistical relations between each component. The model included task and affect network in-degree and out-degree centralities, betweenness centrality, academic score, work group satisfaction, and leader emergence. Each component could be manipulated. More in-degree centrality, more betweenness centrality, and higher test scores all led to increased levels of leader emergence. The focus of this thesis is to understand the antecedents to leader emergence from a system dynamics perspective. The model led to the development of a second model that included personality factors.

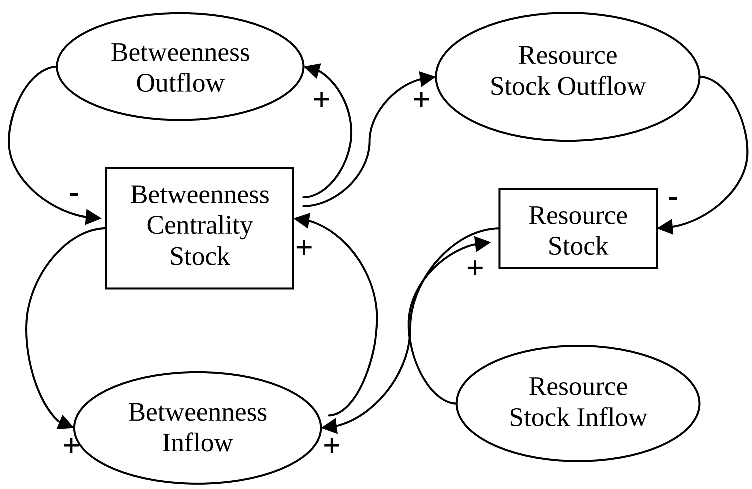
The second model integrated personality factors into the first model. This model included neuroticism, extraversion, openness to experience, agreeableness, conscientiousness, self-monitoring, locus of control, positive affect, and negative affect. While the model demonstrated behavior characteristic of emergent leaders, it did not differentiate leaders and non-leaders. The failure led to two important conclusions for the construction of the final model. First, personalities or their components may influence behaviors. This led to the research of personality constructs. The second conclusion was that that academic score, in-degree centrality, and betweenness centrality were contributing to leader emergence independently. After reviewing the correlation analysis, the scope of the model was reduced to predict betweenness centrality as a system including extraversion and self- monitoring.

With insight gained from the first two models, the final model proved to be more concise. Although the focus shifted to betweenness centrality, it still has implications for leader emergence.

Final System Dynamic Model

The final leader emergence model was the result of several iterations over which it became apparent that personality influences behavior, and leader emergence would best be understood from the sample by modeling betweenness centrality. The correlation results used to refine the scope of the model also found support from empirical research. Betweenness centrality has been shown to strongly predict leadership (Mullen, Johnson, & Salas, 1991). Judge, Bono, Ilies, & Gerhardt (2002) demonstrate a strong correlation for extraversion in thier meta-analysis of personality factors as predictors of leader emergence, and self-monitoring has also been indicated as a predictor of leader emergence (Zaccaro, Foti, & Kenny, 1991; Bedeian & Day, 2004). The set of measures focused on have been selected because they display interrelatedness that academic performance and in-degree centralities do not.

Betweenness centrality displayed an overshoot and collapse structure for high self-monitors. This finding was supported by Moore (2006), in a study of the same sample. The overshoot and collapse causal diagram is shown in Figure IV-1. While this demonstrates the general system structure, an exploration of the resource stock that feeds betweeness will unfold as the personality characteristics are modeled.

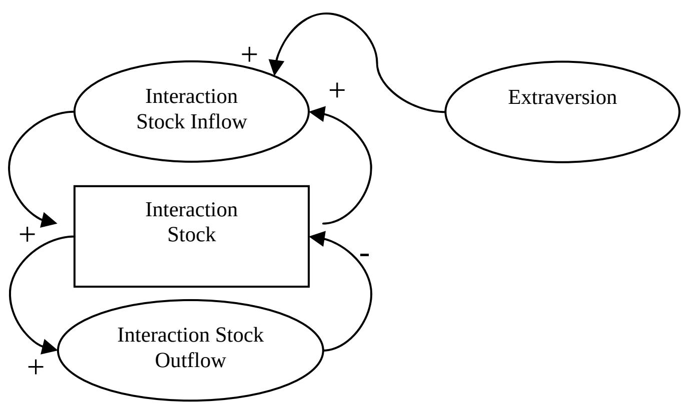


Betweenness Centrality Casual Diagram

Figure IV-1

Betweenness centrality indicates that one is most likely on the path between two other actors in a node. As the density of the network structure increases, betweenness centrality drops (Wasserman & Faust, 1994). The between central actor may bridge ties in such a way that eliminates themselves from being on a path between two other actors. In order to understand the nature of density in relation to the individual, the model needs to incorporate extraversion and self-monitoring into its structure.

In a cross-cultural study, extraversion was shown to be made up of three core components: affiliation, ascendency, and venturesome. These components were a result of an individual's reward sensitivity. In individualist cultures, social situations tend to be rewarding which causes extraverts to be more sociable (Lucas, Diener, Grob, Suh, & Shao, 2000; Asendorpf & Wilpers, 1998). For the purpose of modeling betweenness centrality, the result of extraversion's influence on social interaction was modeled. Interaction is modeled as a first order linear structure. In the model, extraversion ranges from zero (highly introversion) to five, which influences the nature of the behavior. For

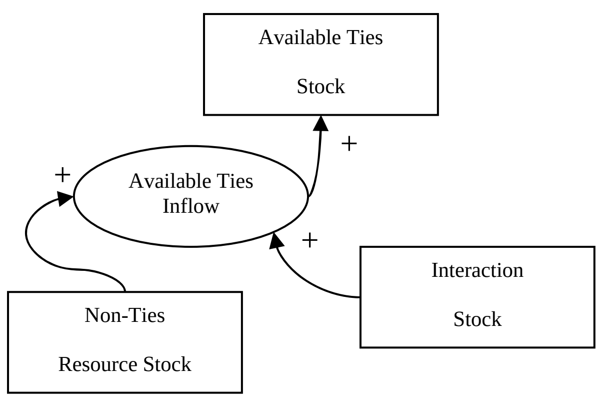


Interaction Causal Diagram

Figure IV-2

introverts, interaction behavior is a first order decay, while for extraverts' interaction behavior is a first order growth. The causal diagram is illustrated in Figure IV-2. Drain on the interaction can be the lack of perceived reward, alternate priorities, or other rewarding opportunities. First order inflow and outflow was selected because the reward experience, or lack of reward experience, from previous interactions feeds both the inflow and the outflow. Interaction adjusts the rate at which an individual converts non-ties to available ties. The resource of non-ties, and their use in the production of available ties, was used to build the next portion of the model.

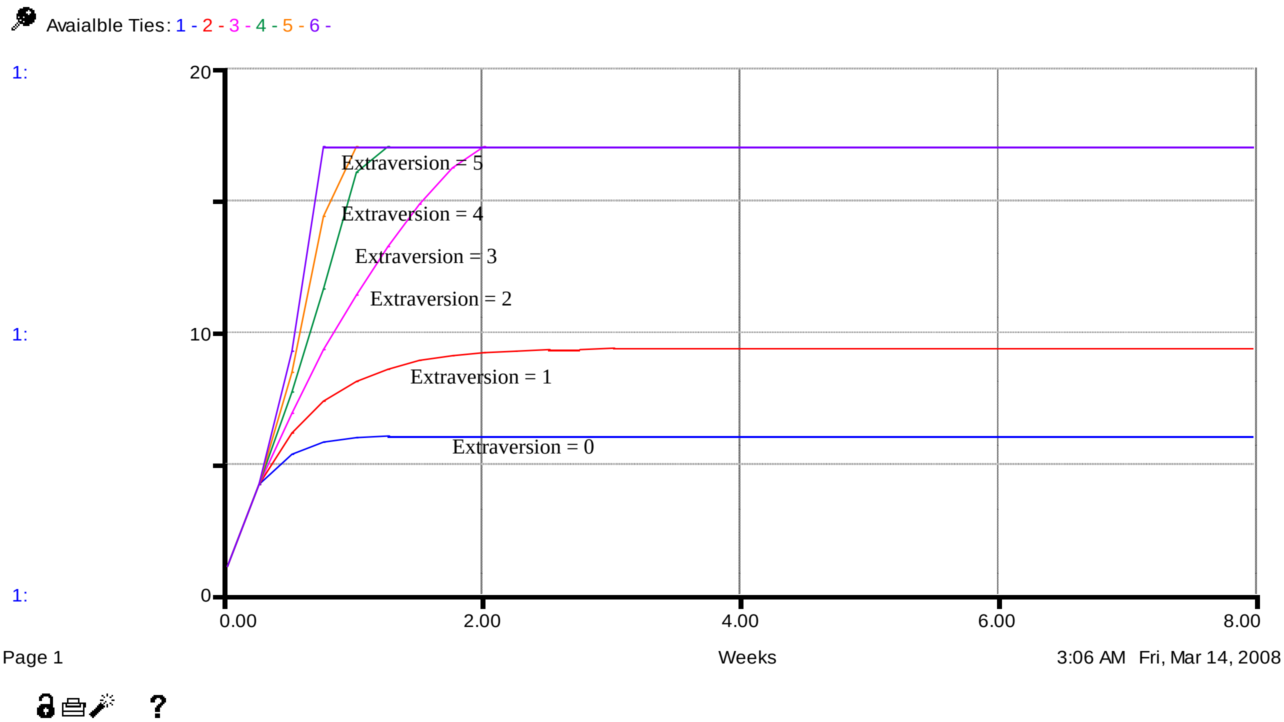
Non-ties represent the initial number of individuals in the group. In the sample, non-ties consist of all individuals within each flight, approximately 16, who are unknown to each other at the beginning of the study.   The casual diagram is shown in Figure IV-3. One uses interaction to produce available ties from these non-ties (Kalish & Robins, 2006). An available tie is one where the individuals have had some rudimentary level of interaction, but does not represent a concerted effort to develop tie strength. The behavior of the level of interaction adjusts the rate at which one initiates contact with



Available Ties Causal Diagram

Figure IV-3

others in the group. The model predicted it takes less time for an extravert to meet all group members than it does for an introvert. This finding is similar to the correlation that affect network out-degree centrality was correlated with extraversion during periods two through five. Figure IV-4 shows the time difference in time to develop available ties for different values of extraversion as determined by the system dynamic model.

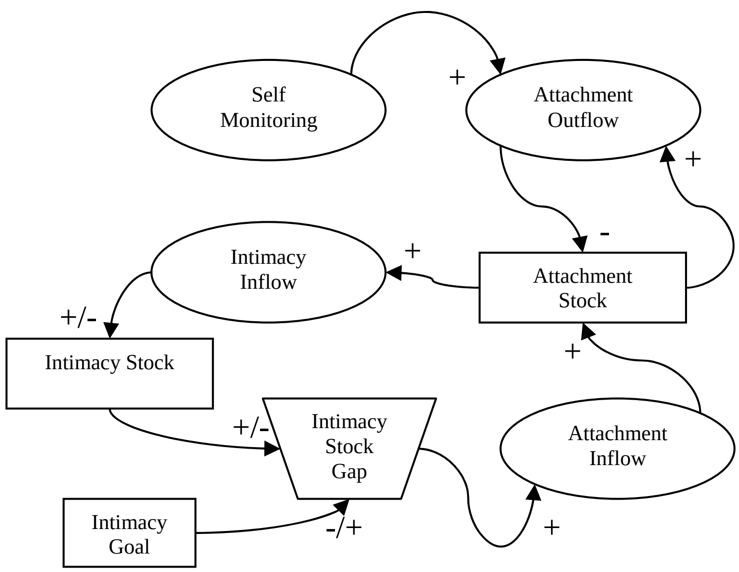


STELLA output of the impact of Extraversion on number of Available Ties over time

Figure IV-4

The resultant behavior of available ties is not surprisingly similar to the behavior for out-degree centrality. While they both reflect the activity of making ties, out-degree centrality measures the activity in terms of time spent per week interacting, while available ties measures the result of the number of individuals interacted with. With the construction of the extraversion portion complete, the next matter for consideration was the contribution of self-monitoring to CAS interaction.

Bartholomew (1990) notes that self-monitoring acts to decrease attachment as a means of regulating the level of intimacy that an individual achieves. Intimacy, as noted by Buhrmester and Furman (1987), is a steady goal over the course of an individual's life. This led to the construction of intimacy as a goal seeking structure. One's constant intimacy goal minus their intimacy stock creates the intimacy gap. Attachment was modeled as an intervening stock, meaning that intimacy is achieved though the fulfillment of attachment. Self-monitoring drains attachment ties that begin to cause an excess in one's desired level of intimacy. Those with low levels of self-monitoring, quickly seek high levels of attachment. Figure IV-5 shows the self monitoring system described.

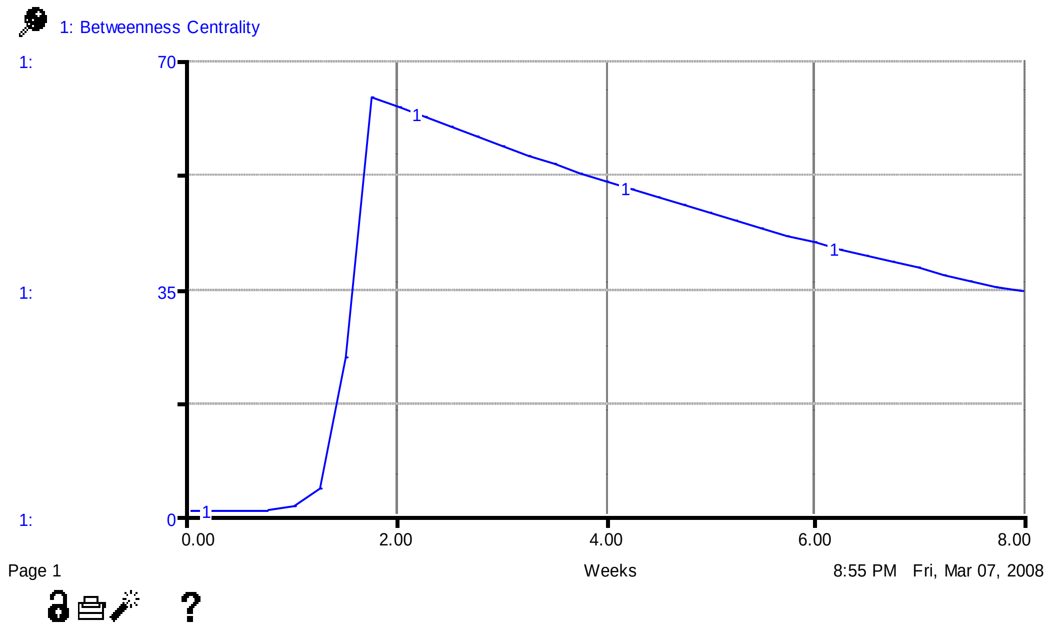


Intimacy and Attachment Causal Diagram

Figure IV-5

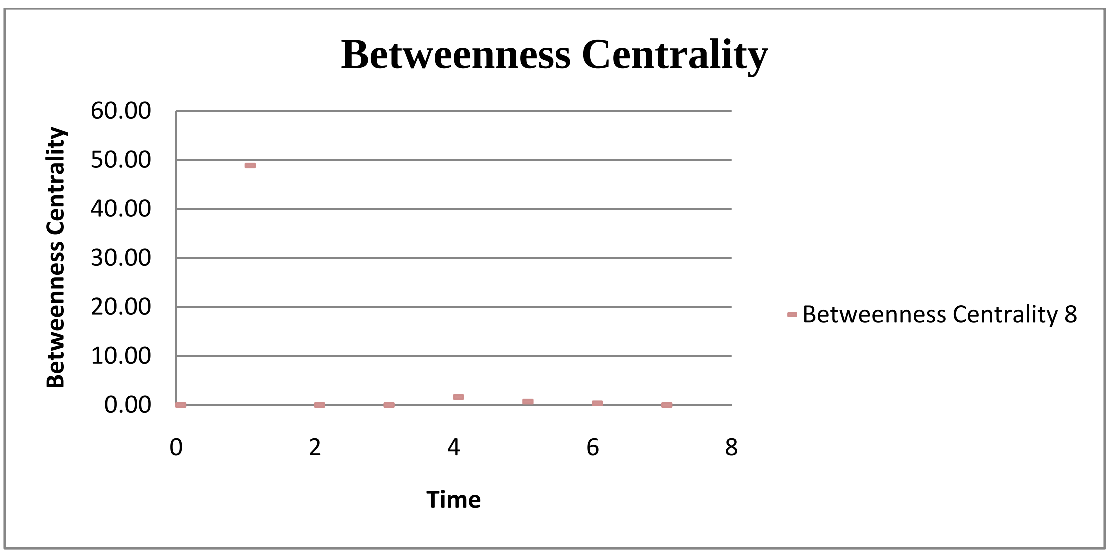
By devoting effort to developing few strong ties, one begins to lose access to ties that were once available. Rejected ties represent those ties that were once available, but through the cultivation of strong ties, become unavailable. The high self-monitor cultivates a high number of weak ties rejecting fewer ties than a low self-monitor in the process. This is supported empirically by Kalish and Robins (2006) who note that high self monitors tend to cultivate triads of weak ties. The result of the self-monitoring system is the quantity of available ties that have been rejected. By combining the extraversion system with the self-monitoring system, the resource for betweenness centrality is modeled.

Betweenness centrality relies on the cultivation of accessible ties as it resource. Accessible ties are those that were developed through one's interaction efforts, and not rejected through their self-monitoring process. A resource of accessible ties resulted in high levels of betweenness centrality. The model was validated by examining the different extremes of extraversion and self-monitoring, and responded similarly to the data. Results of the validation are shown in Figure IV-6, Figure IV-7, Figure IV-8, Figure IV-9, Figure IV-10, Figure IV-11, Figure IV-12, and Figure IV-13. The final STELLA model is shown in Figure IV-14.



STELLA prediction of Betweenness Centrality versus Time for personality profile of Extraversion=4.08, Self Monitoring=.73

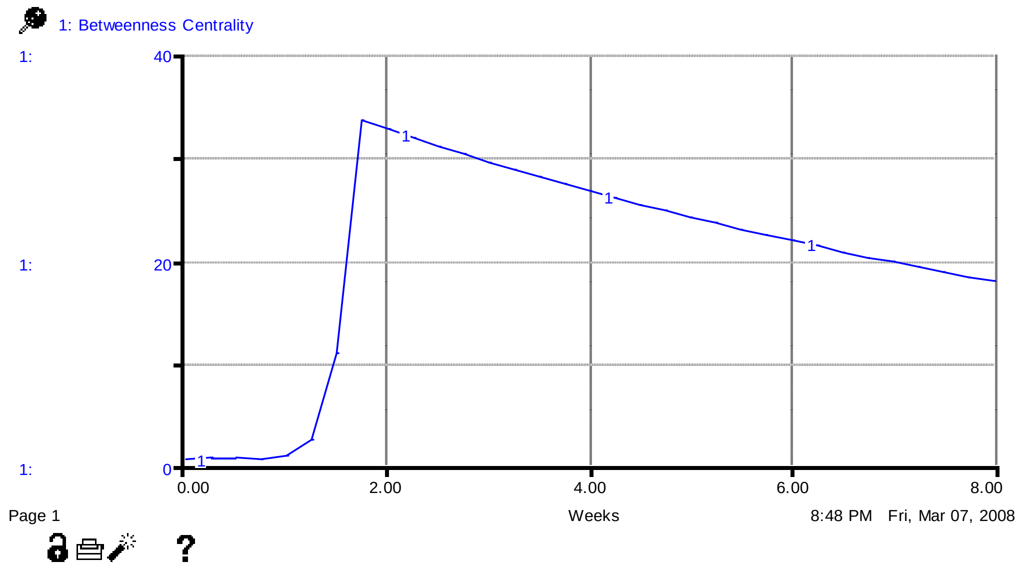
Figure IV-6



Actual Betweenneess Centrality versus Time for personality profile of

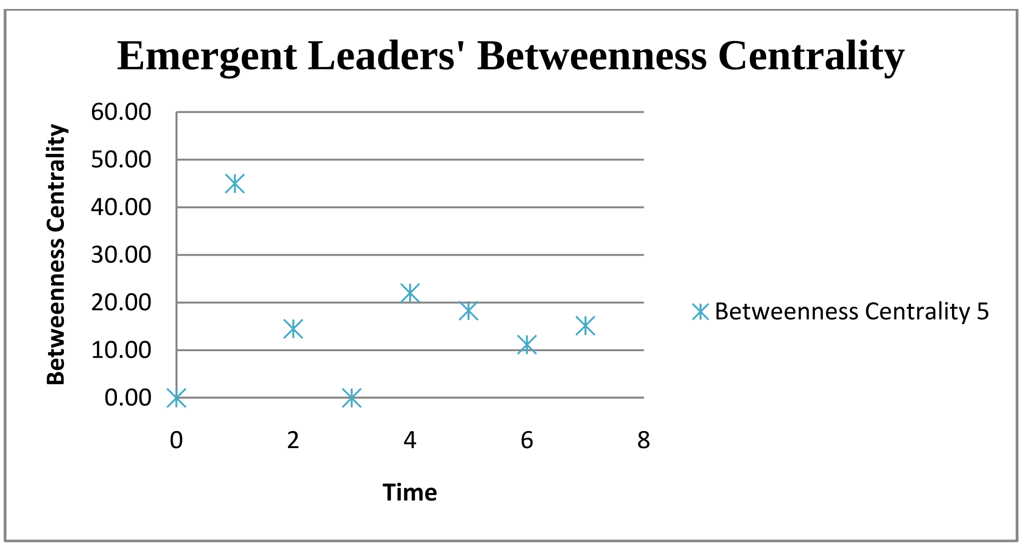
Extraversion=4.08, Self Monitoring=.73

Figure IV-7



STELLA prediction of Betweenness Centrality versus Time for personality profile of Extraversion=2.92, Self-Monitoring=.17

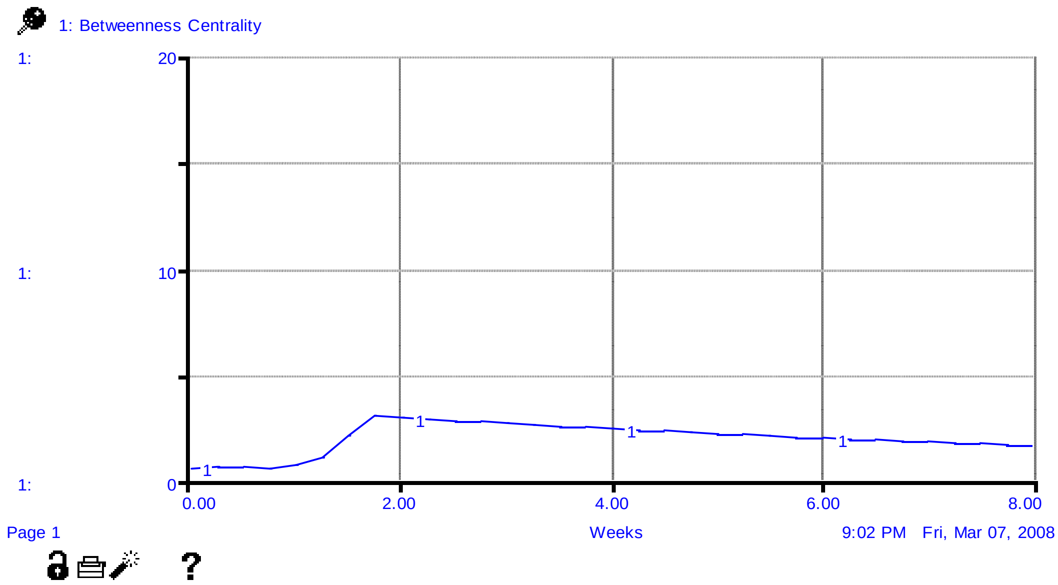
Figure IV-8



Actual Betweenneess Centrality versus Time for personality profile of

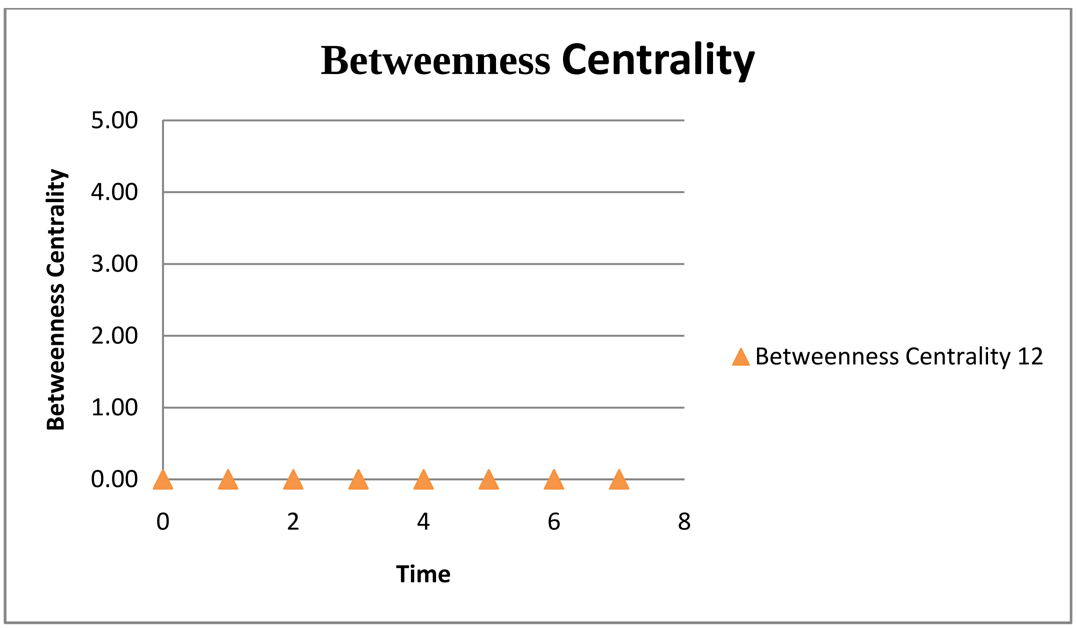
Extraversion=2.92, Self-Monitoring=.17

Figure IV-9



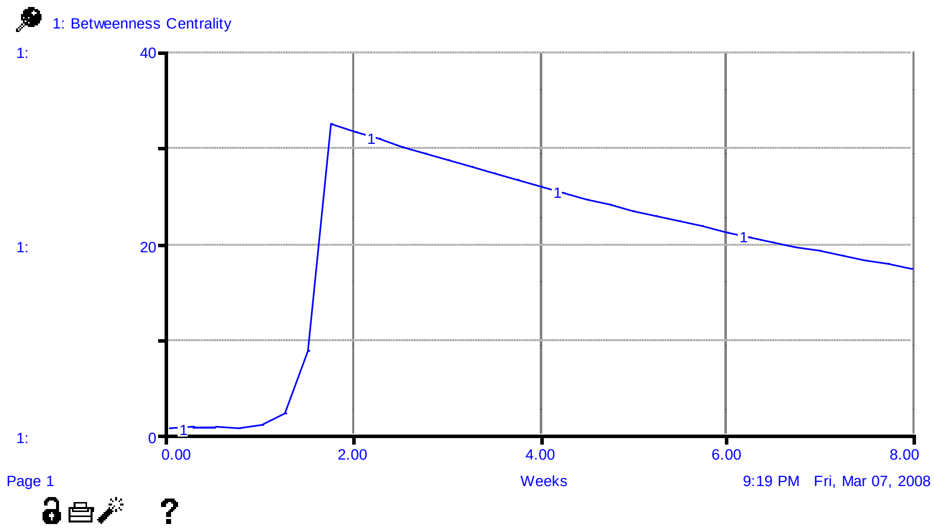
STELLA prediction of Betweenness Centrality versus Time for personality profile of Extraversion=1.15, Self-Monitoring=.11

Figure IV-10



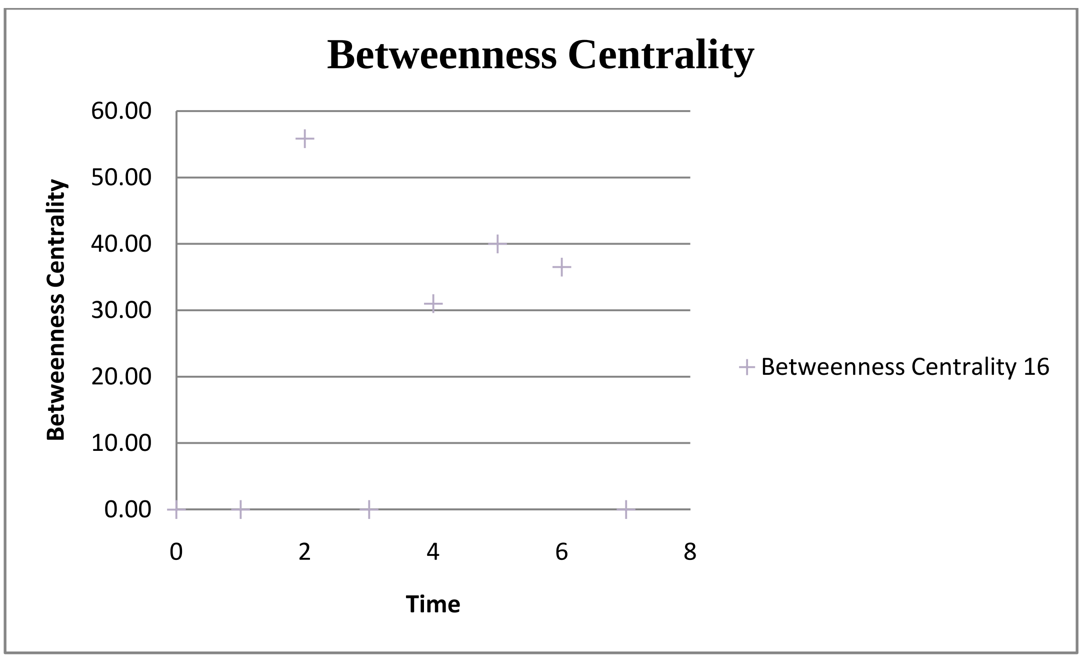
Actual Betweenneess Centrality versus Time for personality profile of Extraversion=1.15, Self-Monitoring=.11

Figure IV-11



STELLA prediction of Betweenness Centrality versus Time for personality profile of Extraversion=2.38, Self-Monitoring=.83

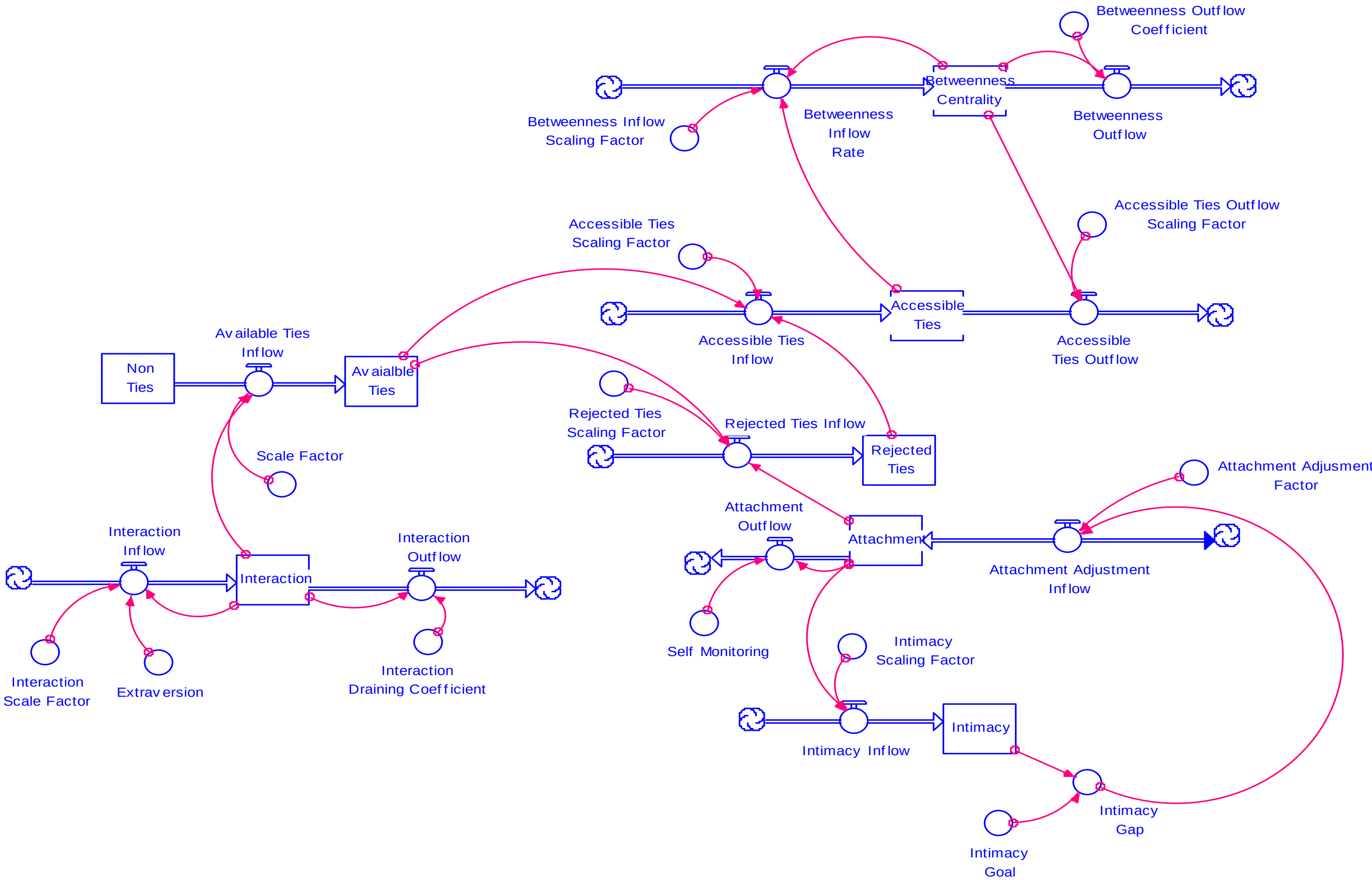
Figure IV-12



Actual Betweenneess Centrality for personality profile of

Extraversion=2.38, Self-Monitoring=.83

Figure IV-13



STELLA model of final system dynamic structure

Figure IV-14

V. Conclusions and Recommendations

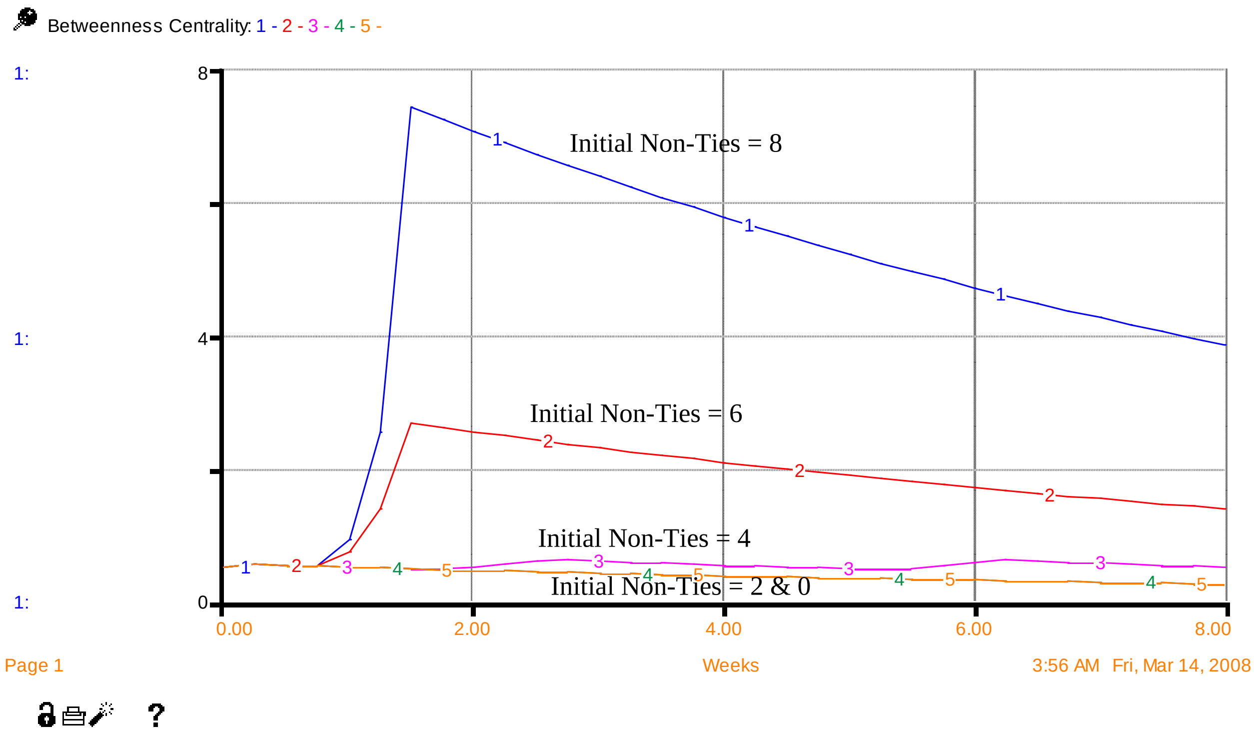
Chapter Overview

This chapter will demonstrate some predictions the model can make about system. The chapter will then cover some assumptions made in the construction of the final model. Reducing the scope of the model became necessary to elucidate betweenness centrality's affect on leader emergence. The chapter will conclude with suggestions for future research to increase the reliability and scope of the model.

System Inquiries

The benefit of system dynamics comes from using the model to answer questions about the system. There are several interesting extensions of the system that can tell us about the possibilities of leader emergence in different situations. The benefit of creating an environment that ensures one's ability to develop betweenness centrality is increasing the possibility for leader emergence. Questions of interest concern factors which restricts betweenness centrality. While there are a limited number of question presented, here, there are no doubt more questions that can be asked within this model, and with the construction of models that improve upon the limitations created by the assumptions discussed later.

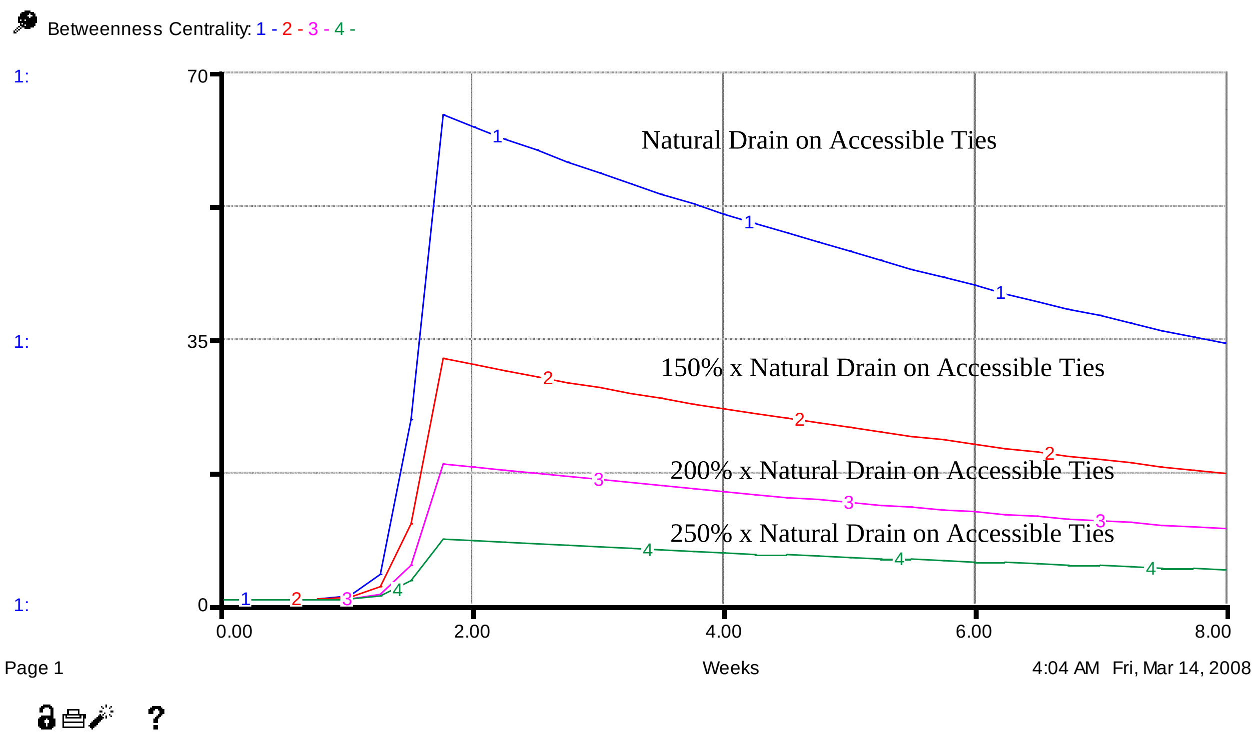
Individuals do not always occupy the same position from one network to the next. When placed in a new environment, there may be fewer non-ties available to the individual. Is there a lower limit of non-ties where betweenness centrality no longer becomes achievable? The system dynamics model predicts that the behavior of betweenness centrality becomes a saw tooth pattern at a lower limit. This result suggests that if an individual is introduced into a group where there is limited access to all members, there is a threshold below which an individual will be unable to establish betweenness centrality. The behavior is shown in Figure V-1



STELLA prediction of impact of initial quantity of Non-Ties on Betweenness Centrality over time

Figure V-1

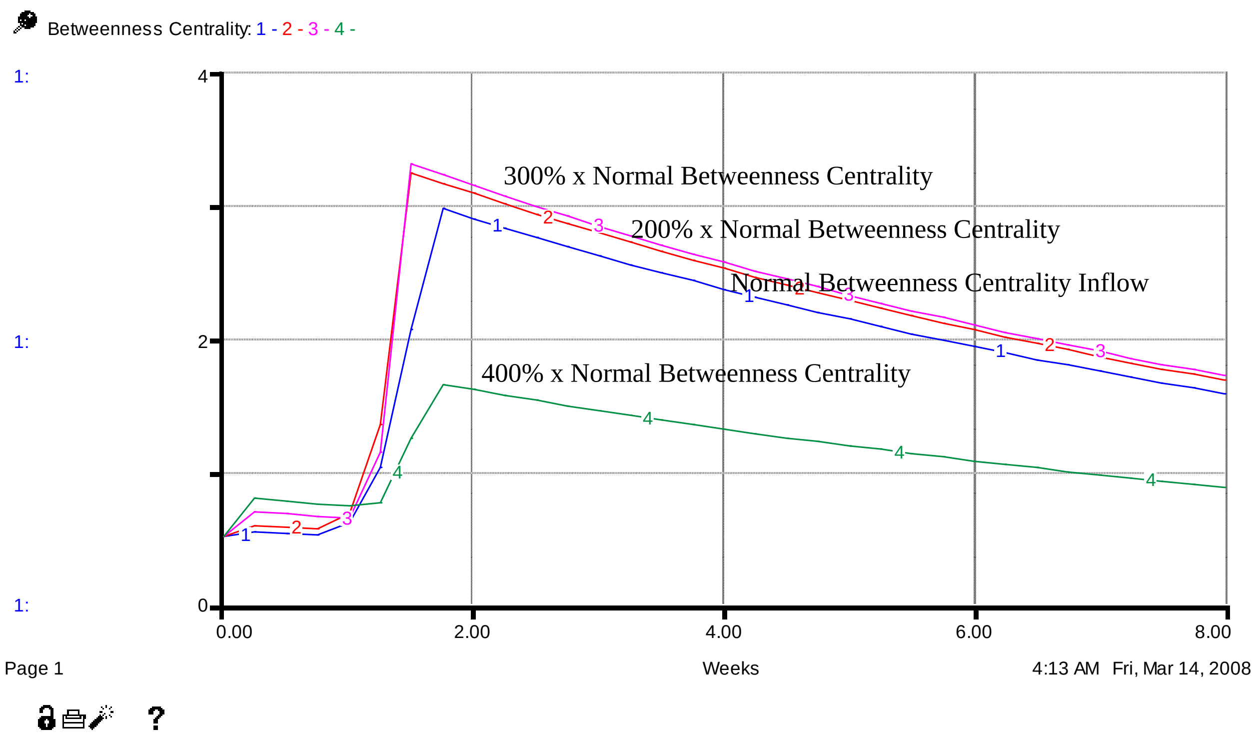
Another question of interest is: what if another individual, who is also displaying a high level of betweenness, is also in the group? This is modeled by increasing the outflow of accessible ties of the individual modeled. While one individual is putting effort into cultivating accessible ties, another more preferred individual is causing those accessible ties increase their own betweenness. The behavior of the curve does not change, and but the individual's betweenness centrality values diminish. In the data, where some groups have several between central actors, those who have the highest leader scores tended to have more betweenness centrality as well. Figure V-2 demonstrates this prediction.



STELLA prediction of impact of drain on Accessible Ties caused by other's Betweenness Centrality

Figure V-2

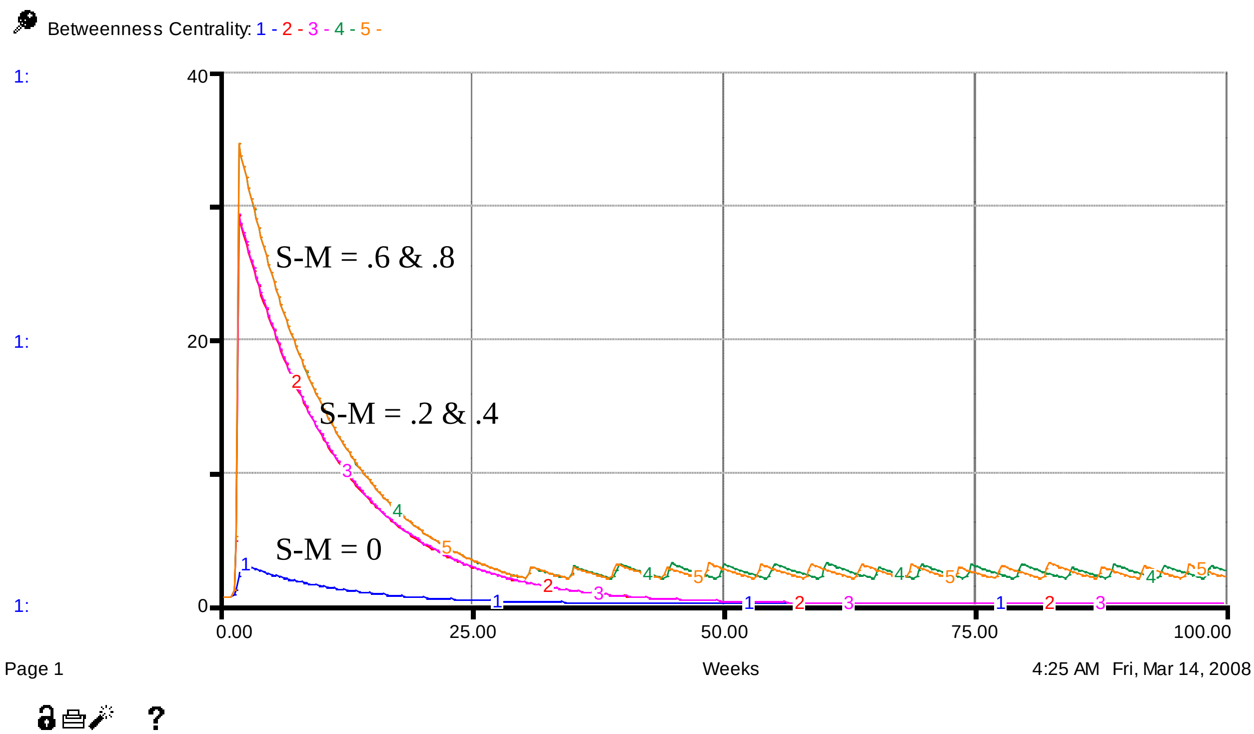
Assume an individual is placed in a liaison position in an organization where they are forced to act as a between central individual. Here the inflow of betweenness is increased through a formal role designation. In the model, the person who is naturally disposed to have a betweenness centrality will have their betweenness centrality amplified. However, a person who is not predisposed for high levels of betwennness centrality, will not benefit significantly in their betweenness centrality, and there is a threshold where their betweenness centrality will be negatively affected. The impact of the a formal designation of betweenness centrality on one who is not predisposed for betweenness centrality is shown in Figure V-3.



STELLA prediction of impact of formal Betwenness Centrality for personality with naturally low levels of Betweenness Centrality

Figure V-3

The final question is: what happens over extended periods of time?   Will certain personality profiles retain some level of betwenness centrality while others deplete any gained? When extended to 100 weeks, the model predicts that those with low levels of self-monitoring will ultimately lose their betweenness, while those with high levels of self monitoring will in the long run retain some level of betweenness. The prediction is shown in Figure V-4.



STELLA prediction of Self-Monitoring's (S-M) impact on Betweenness Centrality over extended time

Figure V-4

These questions help understand different variations of the environment that a sample may be exposed to. While there are other factors which contribute to leader emergence, such as academic score, and in-degree centrality, the model focused on betweenness centrality and the contribution of extraversion's affect on interaction, and self-monitoring's affect on the number of rejected ties.

Model Assumptions

The model generalized the effect of extraversion on interaction. A cross-cultural study found that the components of extraversion (affiliation, ascendency, and venturesome) are driven by reward sensitivity, while positive affect's influence remained unclear. Because of the nature of social situations in individualistic cultures, extraversion correlated with sociability more significantly in those cultures (Lucas et al.). Because our sample was drawn from individuals predominantly from an individualistic culture, extraversion influencing interaction was appropriate for this model. This assumption limits the the model to individualistic culture scenarios.

The second assumption was that in-degree centrality, academic score, and betweenness centrality contributed in equally to the leader emergence process. While the model showed reliability for leaders and non-leaders alike in the development of their betwenneess centrality, it is assumed that the process of leader emergence will not occur without all three components, so all are of interest. This assumption limits the model to situations where betweenness centrality is a requirement for leader emergence. In some cases, other leadership roles may take precedence in leader emergence.

The final assumption was that the individual's personality affects their betweenness despite other CAS dynamics that may be occurring. While the sample was limited in their ability to spend time outside their flights, larger organizations do not typically suffer from such limitations. Thus the model works with the limitation that the same group will be living and working in close proximity.

Future Research

Exploring extraversion may require understanding behaviors that influence each component. In the same way self-monitoring influences the accumulation of attachment, some known or unknown behavior may influence the accumulation of affiliation experience while others may influence the accumulation of ascendency and venturesome experiences. It is interesting to note that complexity leadership theory describes three roles of leadership: administrative, enabling, and adaptive (Uhl-Bien, Marion, & McKelvey, 2007). These roles may correspond with factors that were correlated with leader emergence, and/or be related to the three components of extraversion. Future research should attempt to model the components of extraversion, and seek time-series data on leader emergence. While extraversion represented a component of the model that was simplified, in-degree centrality and academic score were eliminated when the scope of the model was reduced.

In-degree centrality and academic score demonstrated correlations with leader emergence, and future research may attempt to model those interactions. Understanding the academic scores' impact may be benefit from collecting information on the amount of time spent studying, group study time spent, and participants' awareness of other's grades. In-degree centrality may need to involve the collection of demographic information, and/or qualitative surveys to understand the selection process of certain individuals over others. Several selection processes may be occurring simultaneously during leader emergence, and when a CAS is in an environment where the opportunity to interact freely outside the group exists the model may begin to show very different behavior. By limiting aspects of the environment while constructing reliable models, future models can begin to incorporate exogenous influences.

Conclusion

Leadership research has attempted to describe and understand leader emergence from a linear perspective. Attention in leadership research is turning toward non-linear modeling to describe the complexity associated with leader emergence. This thesis describes how system dynamics can facilitate the understanding of social systems with an investigation of the component parts.

Correlation studies have brought about useful insight into the many facets of leader emergence. While efforts have focused on supporting theories with linear approaches of analysis, complexity theory has found appeal by describing and analyzing leader emergence within group dynamics (Marion & Uhl-Bien, 2001). System dynamics offers an opportunity to understand and communicate social systems with its approach to non-linearity (Forrester, 1987).

People, in their need to rapidly process information, are limited in their ability to develop mental models beyond interpreting information from their immediate surroundings in terms of cause and effect (Sterman, 2000). Previous research supports the existence of the extraversion, self-monitoring, and betweenness centrality as independent components of leader emergence. By using system dynamics, this thesis identified and validated the interaction of extraversion, self-monitoring, and betweenness centrality, producing a model that demonstrates their relationships across time. Instead of accounting for extraversion, self-monitoring, and betweenness centrality as moderating factors of leader emergence, system dynamics required an explanation of their relationship to each other. Given that leader emergence involves individual, group, and environmental factors (Plowman, Solansky, Beck, Baker, Kulkarni, & Villareal Travis, 2007; Marion & Uhl-Bien, 2001), this thesis demonstrates that the system dynamics methodology affords researchers the opportunity to dissect the components of leader emergence, and reassemble them into dynamic and interdependent terms. Because of its iterative and methodological approach, system dynamics can help leader emergence research by understanding the nature of concepts already defined, and directing future research efforts toward concepts that need additional clarification.

Appendix A, Generic system dynamic structures

(Shelley, 2007)

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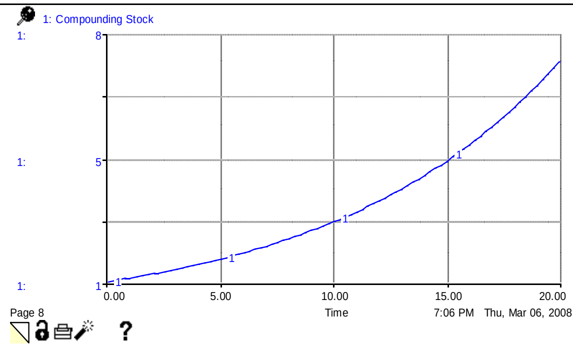

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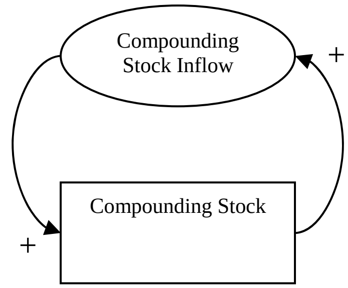

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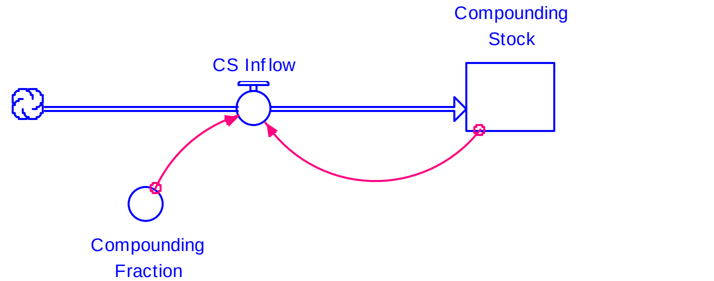

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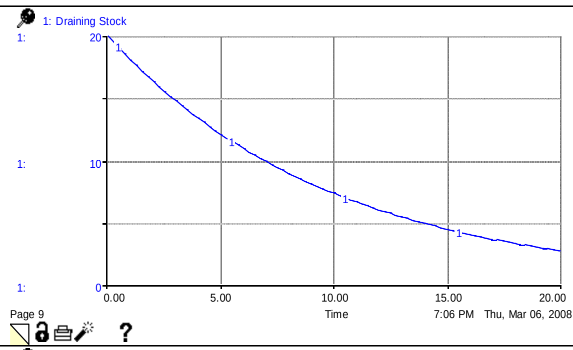

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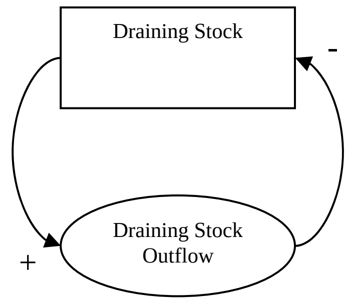

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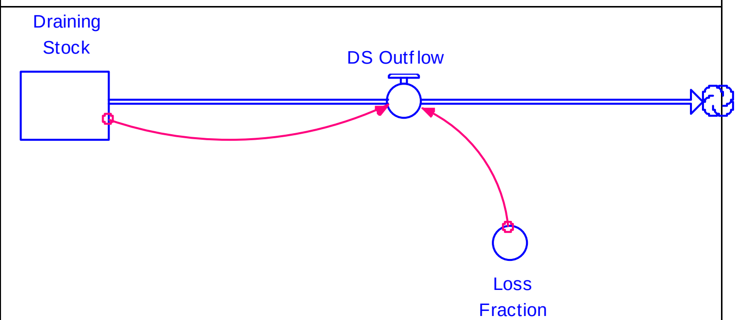

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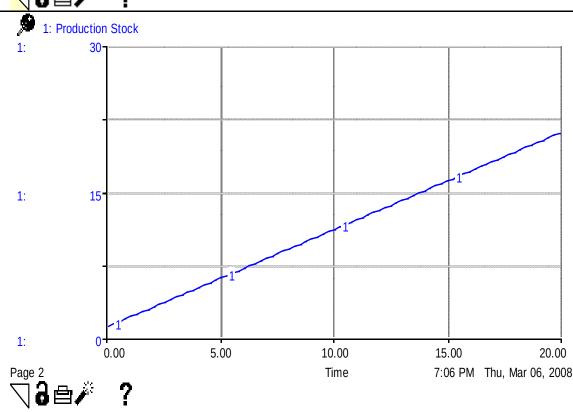

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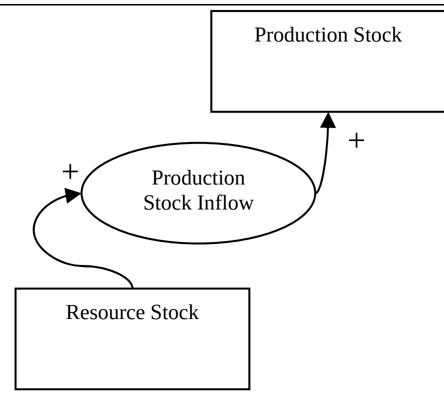

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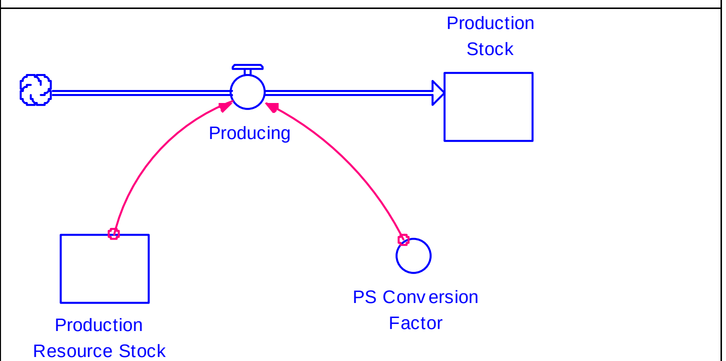

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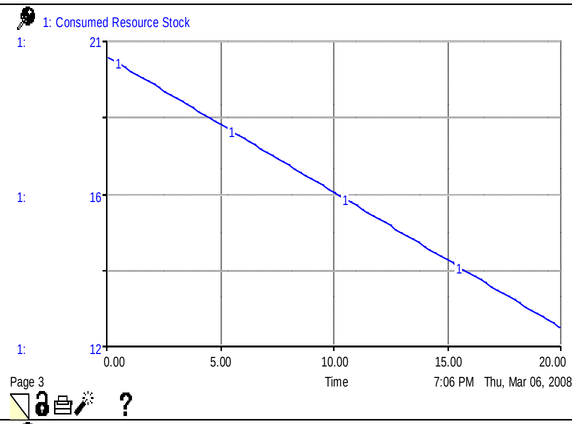
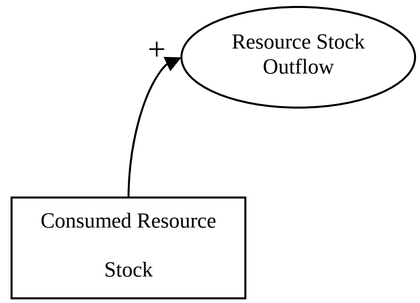
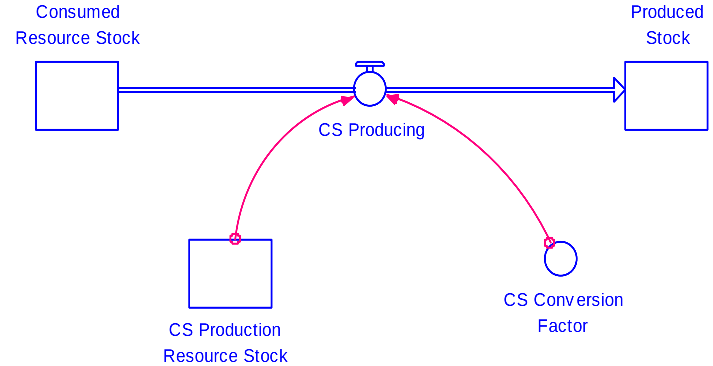
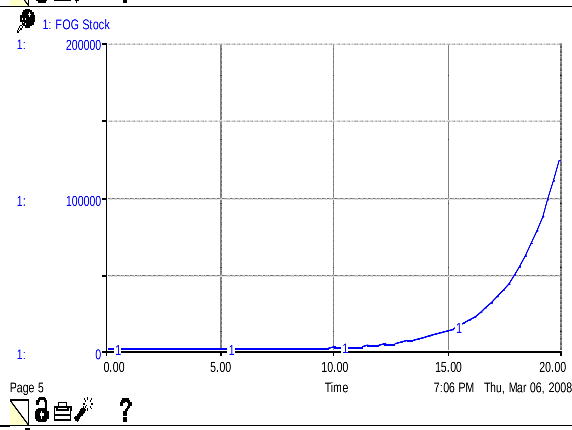
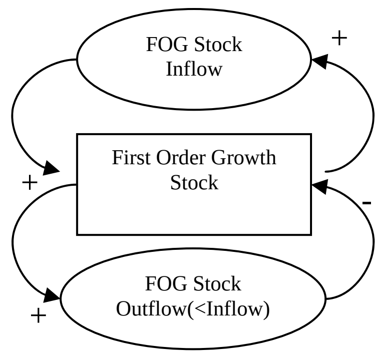
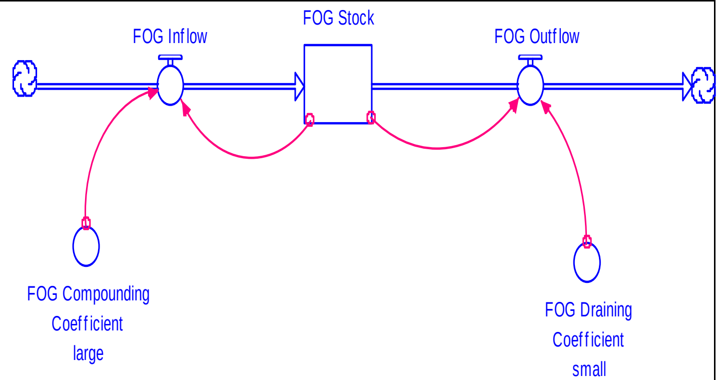
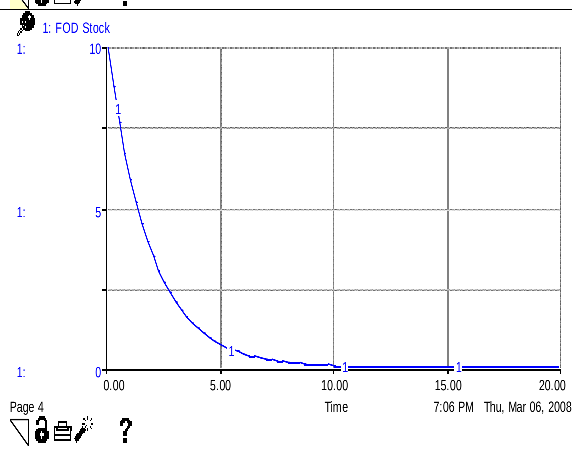
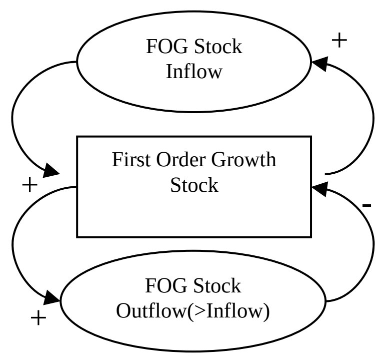
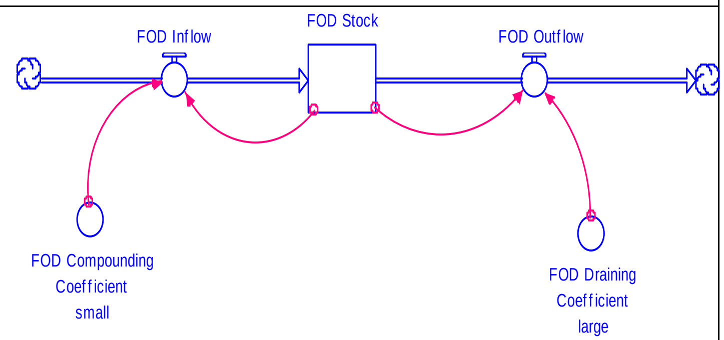
Consuming			
1st Order Growth Linear			
1st Order Decay Linear			

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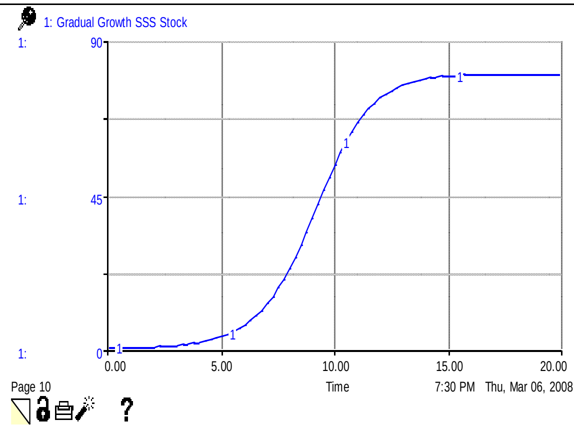
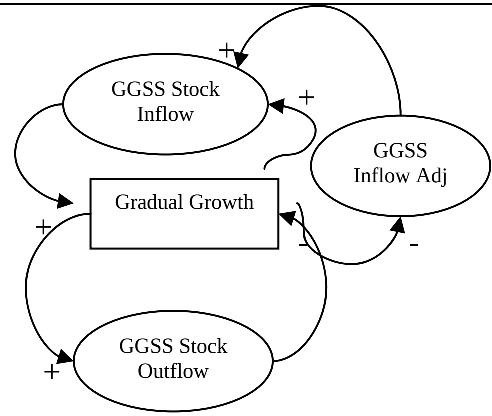
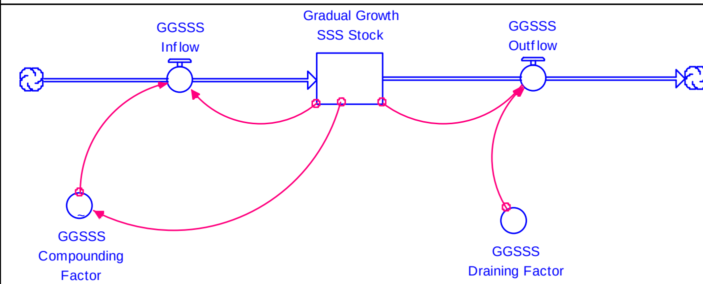
<tr><td>Gradual Growth S-Shaped</td><td>
</td><td>
</td><td>
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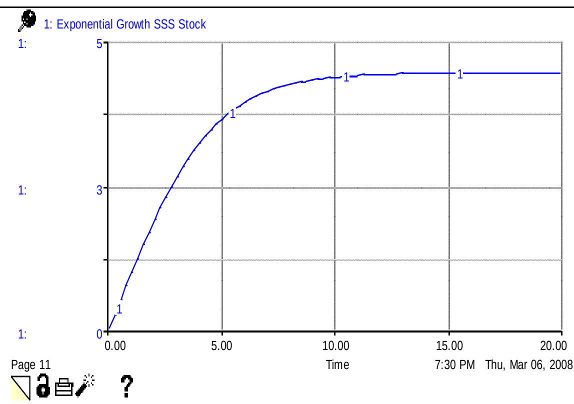
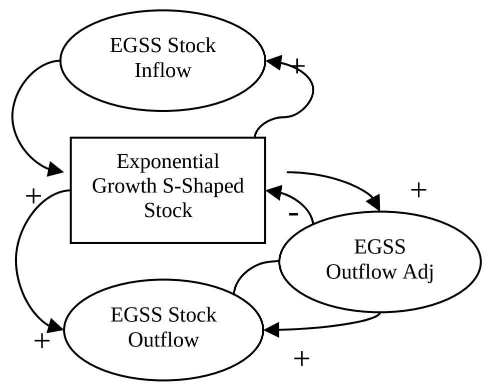
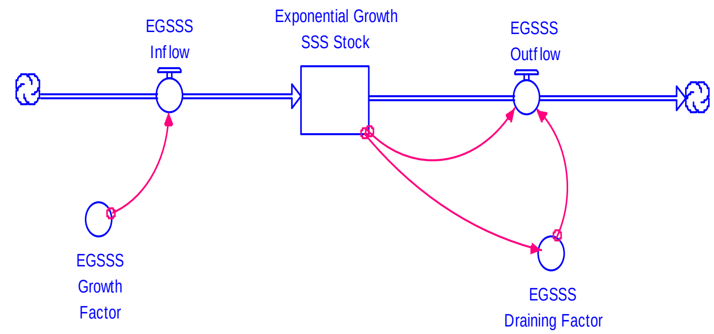
<tr><td>Exponential Growth S-Shaped</td><td>
</td><td>
</td><td>
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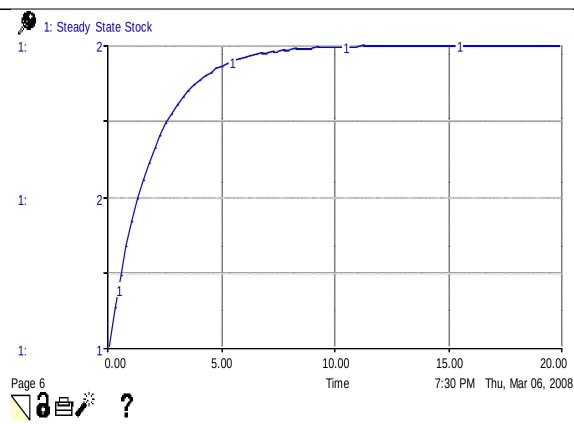
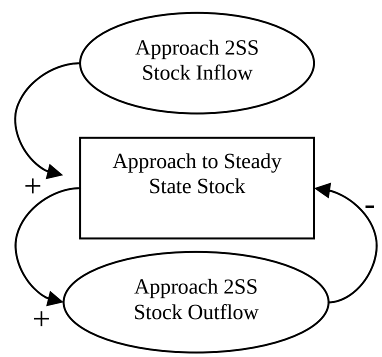
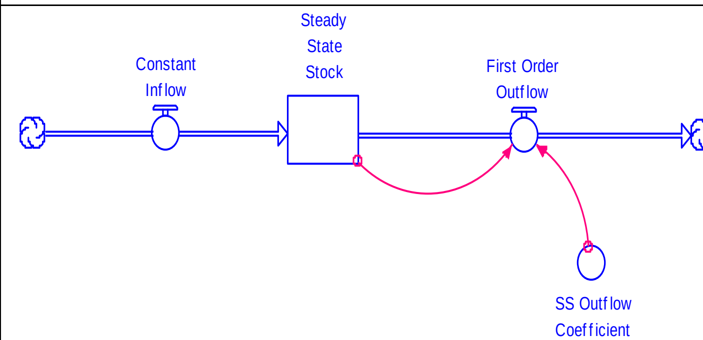
<tr><td>Approach to Steady State</td><td>
</td><td>
</td><td>
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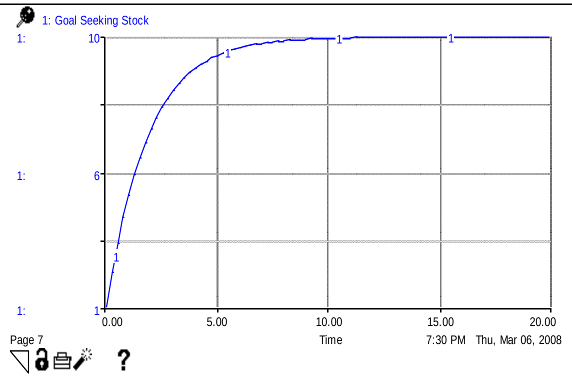
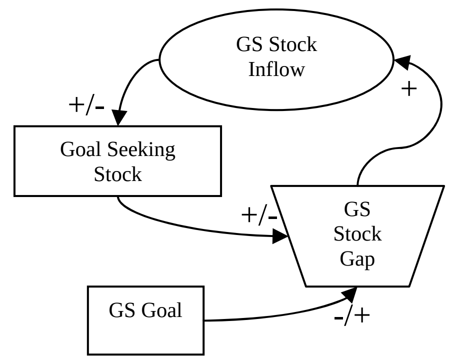
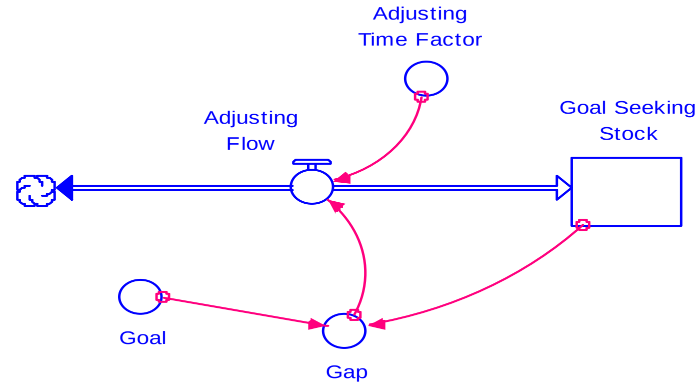
<tr><td>Goal Seeking</td><td>
</td><td>
</td><td>
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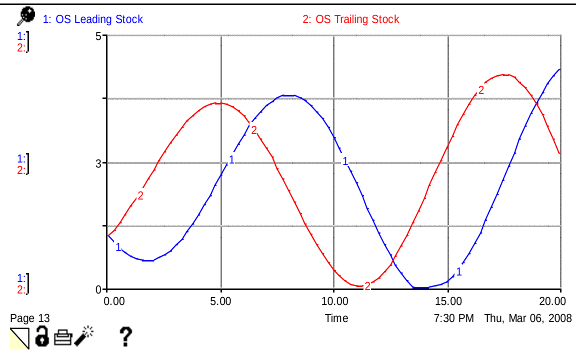
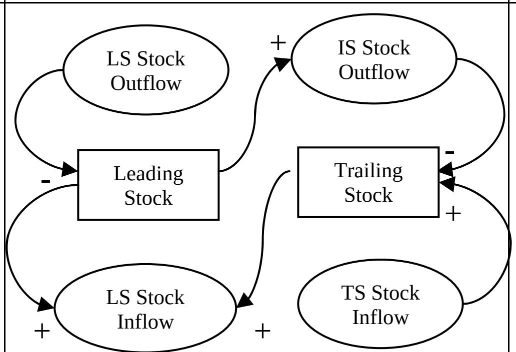
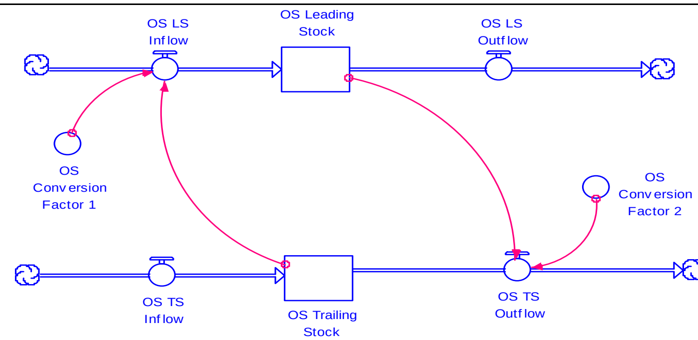
<tr><td>Oscillation Structure</td><td>
</td><td>
</td><td>
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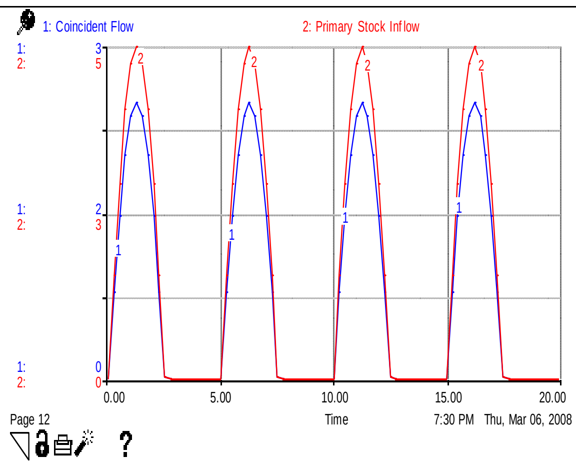
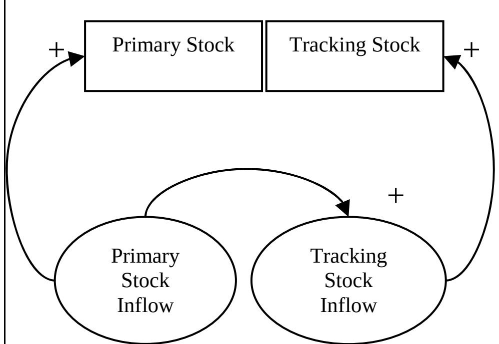
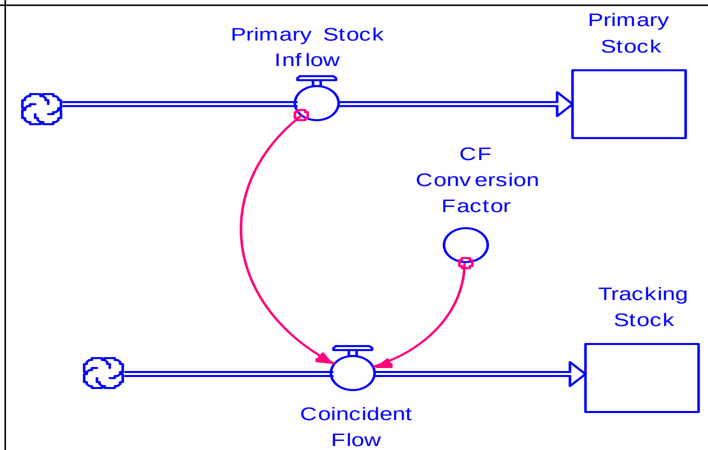
<tr><td>Coincident Flow</td><td>
</td><td>
</td><td>
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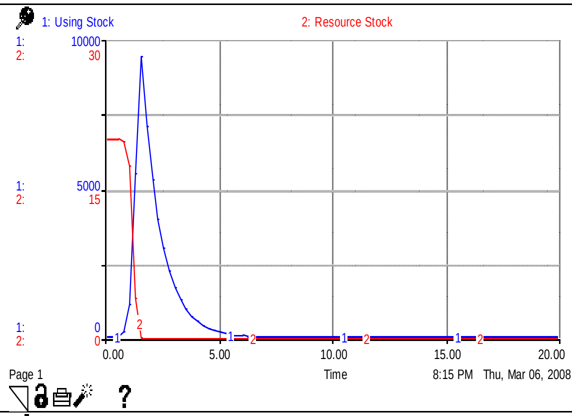
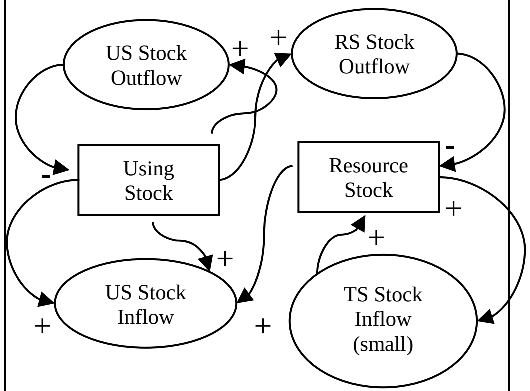
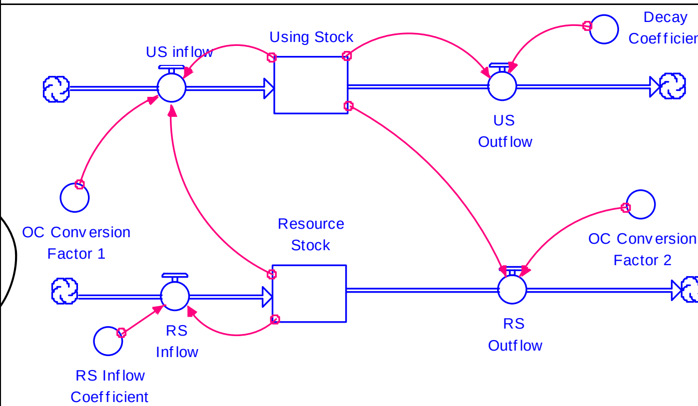
<tr><td>Overshoot & Collapse</td><td>
</td><td>
</td><td>
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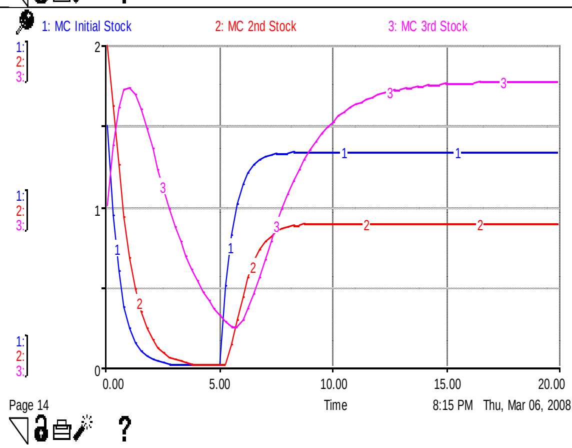
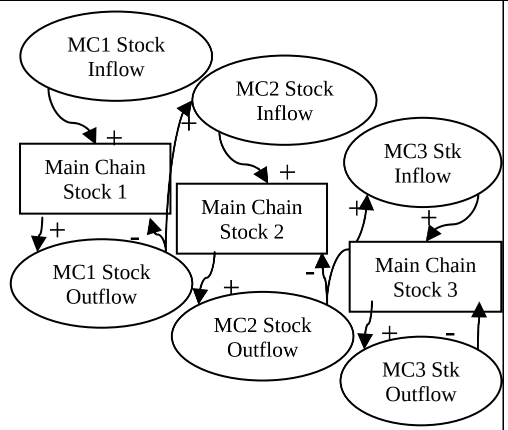
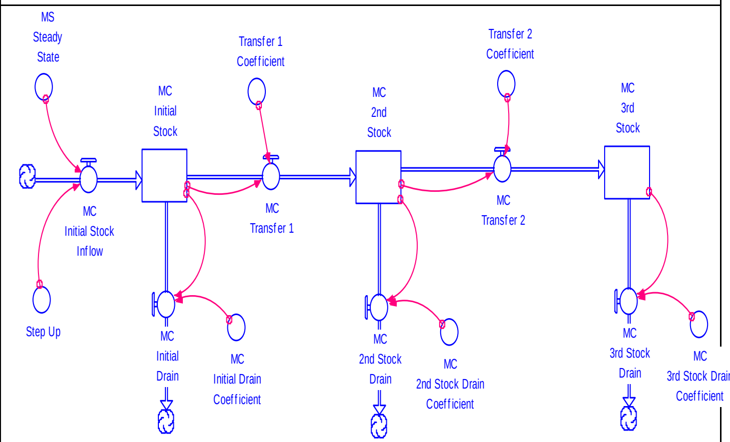
<tr><td>Main Chain</td><td>
</td><td>
</td><td>
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14. ABSTRACT

The purpose of this thesis is to develop a system dynamics model of leader emergence. Longitudinal social network and personality data were collected in a class of enlisted military professionals attending a six week leadership development course. Findings support known relationships in existing leadership research. This thesis demonstrates the applicability of system dynamics toward the complex social phenomena of leader emergence.

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